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WHOI-90-14

Wind and Wave Climatology on the New England Shelf May 1987 – August 1988

by

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February 1990

Technical Report

Funding was provided by the Office of Naval Research through contract Number N00014-86-K-0715 under the University Research Initiative Program.

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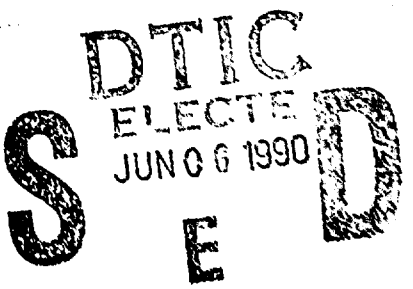

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May 1987 – August 1988

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Abstract

Wave power spectra from four waverider buoys on the New England Shelf and wind velocity records from three of those buoys and a fixed platform were analyzed. The data span the period from May 1987 through August 1988. Time series plots of significant wave height, mean wave period and modal (peak) period and distribution histograms of significant wave height, mean frequency and modal frequency are presented for the two buoys nearest to Martha's Vineyard. Time series plots of wind speed and vector velocity and distribution histograms of speed and direction are plotted for one buoy and the platform. For all stations, monthly and seasonal mean and extreme values of significant wave height, mean and modal wave periods, wind speed and mean weighted and unweighted values of wind direction are provided in tabular form. Five and ten year extreme wave height predictions are also calculated.

1 Overview

1.1 Objectives

This technical report provides time series, histograms and extreme value wave height analyses which detail the changing wind conditions and sea states on the New England Shelf. The products in this document are designed to facilitate both qualitative and quantitative interpretation of the data.

Time series in this report are presented on identical scales to allow side-by-side comparison of different data in the same time period. For example, the vector plot of wind velocity can easily be compared with the the significant wave height time series for the same period. In this way, event durations, maximum values, times of steady conditions or rapid change, and other characteristics of interest may be estimated by inspection or their occurrences noted for detailed investigation.

Histograms are provided to approximate the distributions of values for selected parameters.

The 18 month record of significant wave height is evaluated using extreme value analysis and the resulting five and ten year return period wave heights are tabulated.

1.2 Summary of Graphs and Tables

Graphs and tables in this report are described in detail in Section 3, Data Analysis. Data are presented graphically for Martha's Vineyard Buoy, Buzzards Bay Tower and Buoy 44008, the nearest stations to Martha's Vineyard. Tabular information is presented for all stations. The tables and graphs are listed here.
Wave Data Time Series:

- Significant Wave Height (H_s)
- Mean Wave Period ($\overline{T}$)
- Modal (Peak) Wave Period (T_m)

Wave Data Histograms:

- Significant Wave Height
- Mean Frequency ($\bar{f} = 1/\bar{T}$)
- Modal (Peak) Frequency ($f_m = 1/T_m$)

Wind Data Time Series:

- Wind Speed (U_{10})
- Vector Velocity (U_{10} at angle θ)

Wind Data Histograms:

- Wind Speed

- Wind Direction

Wave Data Tables, Monthly and Seasonal Summaries:

- Significant Wave Height
  Minimum, Mean and Maximum
- Mean Wave Period
  Minimum, Mean and Maximum
- Modal Wave Period
  Minimum, Mean and Maximum

Wind Data Tables, Monthly and Seasonal Summaries:

- Wind Speed
  Minimum, Mean and Maximum
- Mean Direction (weighted by speed)
- Mean Direction (unweighted)

Extreme Value Analysis, by Calendar Month:

- Mean Significant Wave Height
- Expected Five Year Extreme Significant Wave Height
- Expected Ten Year Extreme Significant Wave Height

2 Data Sources

2.1 Buoy and Platform Locations

Wave and wind data were recorded at the following stations:

Station Name	Organization	Data Type
Martha's Vineyard Buoy	WHOI	Wave
Buzzards Bay Tower	NODC	Wind
Buoy 44004	NODC	Wave & Wind
Buoy 44008	NODC	Wave & Wind
Buoy 44011	NODC	Wave & Wind

Station locations are given below and are shown in the charts of Figure 1 and Figure 2.

Station Name	Latitude	Longitude	Depth
Martha's Vineyard Buoy	41° 16′ N	71° 02′ W	42 m
Buzzards Bay Tower	41° 24′ N	71° 00′ W	11 m
Buoy 44004	38° 30′ N	70° 36′ W	3231 m
Buoy 44008	40° 30′ N	69° 30′ W	60 m
Buoy 44011	41° 06′ N	66° 36′ W	93 m

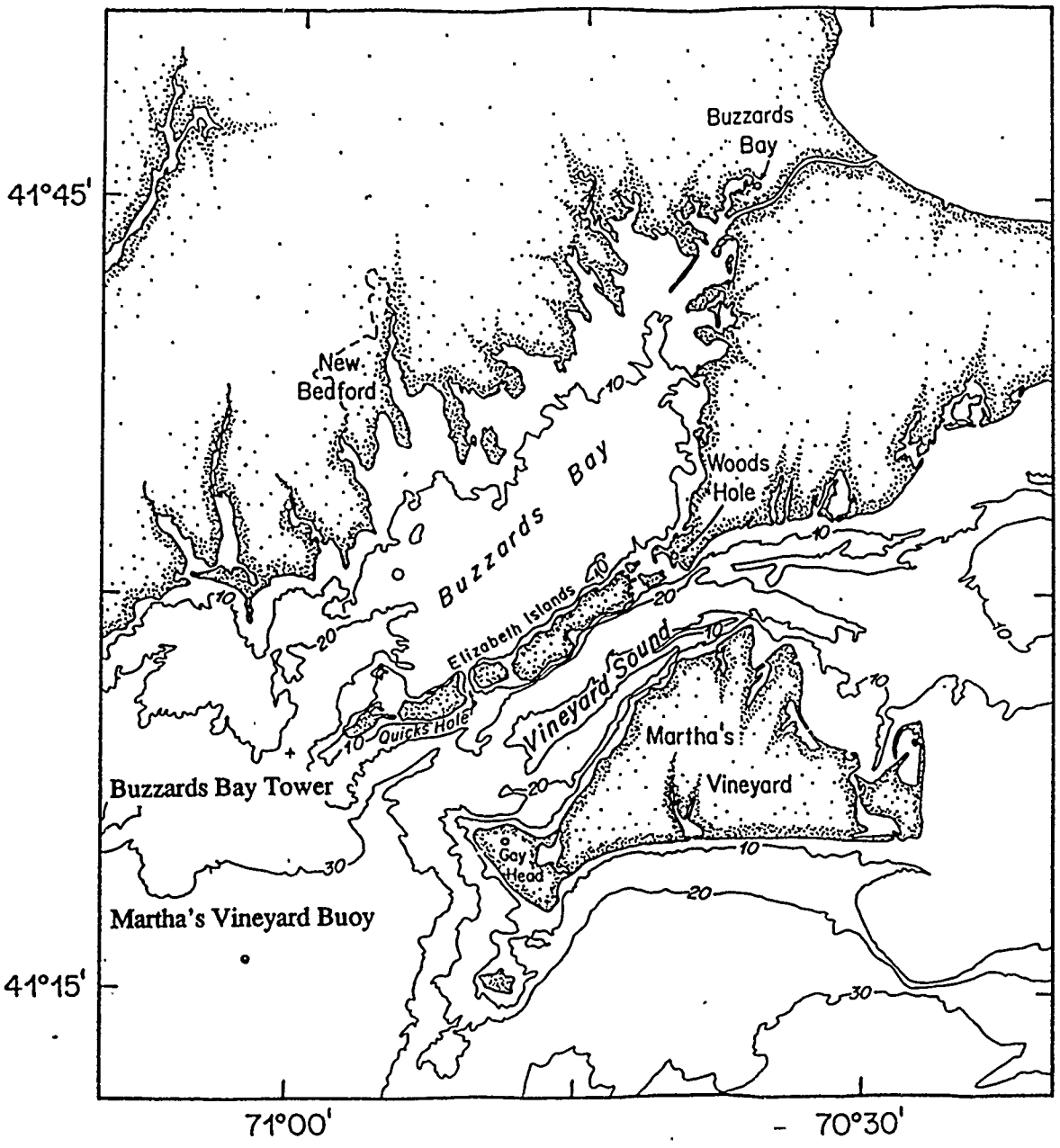

Figure 1: Buoy and Platform Locations Near Buzzards Bay

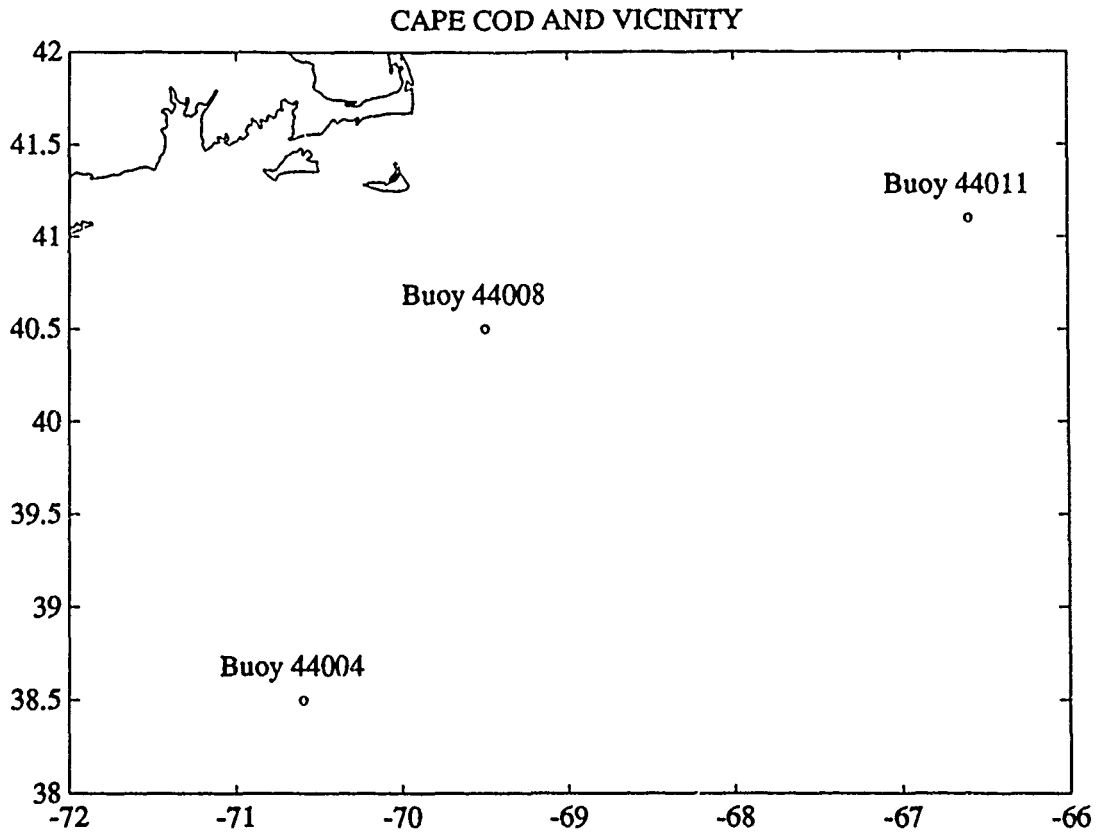

Figure 2: Buoy Locations on the New England Shelf

2.2 Data Formats

2.2.1 NODC Sources

The National Oceanographic Data Center (NODC) waverider buoys sampled sea surface height at a rate of 1.5 Hz during a 20 minute sampling interval. The time series of surface elevations were processed and available as wave energy spectra. Environmental data from the NODC stations were obtained on nine-track tapes in ASCII as Meteorology and Wave Spectrum File 191 format files. See NODC (1986) for a detailed description of the File 191 format and other information about data products available from NODC. These files provided hourly summaries of environmental conditions.

2.2.2 WHOI Sources

The Martha's Vineyard Buoy Telemetry Project was operated by the University Research Initiative Program at WHOI. A general goal of the project is to develop techniques for gathering *in situ* data from the ocean and disseminating them to users in a timely and efficient way. A secondary objective was to test the feasibility of this telemetering technique for long-term surface wave monitoring in coastal waters. The waverider sampled sea surface

height at the rate of 2 Hz during sampling i.. :als of 17 minutes centered on each hour and half hour. The buoy did not have meteorological sensors but was located near the instrumented Buzzards Bay Tower (Figure 2). The Martha's Vineyard Buoy wave data were obtained as summary files and spectrum files. Details of the data acquisition, processing and dissemination are described by Briscoe et al. (1988). The data files contain an environmental summary for each half-hour period.

3 Data Analysis

3.1 Wave Data

3.1.1 Definitions

The n^{th} moment of a continuous spectrum is

$$m_n = \int_0^\infty f^n \, S(f) \, df \tag{1}$$

where $S(f)$ is the spectral density at frequency f and has units of m^2/Hz. For the NODC buoys, using samples of the spectral density at discrete frequencies $S(f_i)$, (1) can be expressed as

$$m_n = \sum_{f_i=f_{min}}^{f_{max}} f_i^n \, S(f_i) \, \Delta f \tag{2}$$

with f_{min}, f_{max} and Δf given in Table 1.

The spectrum files for WHOI's waverider buoy list the spectral energy, E_{f_i}, in each frequency interval, not the energy density, $S(f_i)$. These are related by

$$E_{f_i} = S(f_i) \, \Delta f \tag{3}$$

with $\Delta f = 1/128 \, Hz$ for these records. The spectral energy, E_{f_i}, has units of m^2. For the WHOI buoy, using spectral energy in each frequency interval, (2) can be written as

$$m_n = \sum_{f_i=f_{min}}^{f_{max}} f_i^n \, E_{f_i} \tag{4}$$

Frequency information for the four buoys is listed in Table 1.

Station	f_{min}	f_{max}	Δf	Intervals
Martha's Vineyard	4/128	63/128	1/128	60
Buoy 44004	0.03	0.50	0.01	48
Buoy 44008	0.03	0.40	0.01	38
Buoy 44011	0.03	0.50	0.01	48

Table 1: Low and High Cut-Off Frequencies in Hz for Waverider Buoys.

3.1.2 Data Preparation

Significant wave height, H_s, is derived from the zero'th spectral moment using the following definition:

$$H_s = 4\sqrt{m_0} \tag{5}$$

Significant wave height is conventionally defined to be the average height of the one-third highest waves in a time series. As used here and defined in (5), H_s is also a measure of the total energy of the wave spectrum. These two definitions agree well for narrowband spectra, i.e., for spectra in which most of the energy is concentrated in a narrow range of frequencies, which is typically located around the peaks. Ochi (1982) has explored the agreement of the two definitions for various sea conditions.

Mean wave period, $\bar{T}$, is the reciprocal of the mean wave frequency, $\bar{f}$, and is given by

$$\bar{T} = m_0/m_1 \tag{6}$$

A more correct name for mean frequency, $\bar{f}$, is the centroid frequency of the energy spectrum. See Nath and Yeh (1987) for a discussion of this issue. The mean wave period, $\bar{T}$, as defined in (6), is one measure of the wave period about which energy is concentrated. For the general case of a bimodal or a multi-modal spectrum, $\bar{T}$ may actually fall between spectral peaks in a part of the spectrum with relatively little energy.

The modal (peak) period, T_m, is chosen simply as the frequency corresponding to the largest spectral energy density.

The mean, median, mode, percent above the mode and standard deviation were calculated for the above quantities for each month. In finding the mode for these continuous values, the range of each was divided into appropriately sized bins, and the value of the bin with the most occurrences assigned as the mode.

3.1.3 Presentation

Significant wave height, mean wave period, and modal wave period are plotted as time series of hourly values in bar graph format. Each plot covers one calendar month.

Significant wave height is presented again in monthly histogram format. Each value of significant wave height is assigned to a bin. The distribution of significant wave heights varies with the seasons. To aid in standardizing these histograms, the bins are not based on absolute wave heights but on standard deviation units. Bin zero is centered on the mean and bins are spaced at intervals of 0.2 standard deviation units. Each bar of the histogram represents the percentage of wave heights assigned to that bin.

Modal frequencies, the frequencies corresponding to the peak spectral energy densities, and mean frequencies are also plotted as histograms. Modal frequency is the inverse of modal period:

$$f_m = 1/T_m \tag{7}$$

and mean frequency is the inverse of mean period:

$$\bar{f} = 1/\bar{T} \tag{8}$$

Frequency is used here because the discrete frequencies for which we are given spectral energy densities are equally spaced while their corresponding periods are not. The bins are in units of frequency and the bars again represent the percentage of peak frequencies in each bin.

Summaries of significant wave height, modal wave period and mean wave period are presented in tabular form. The first section of the table for each station shows the minimum value, mean value and maximum value for each quantity during each month. The second part of the table is similar but displays the information over seasons, not months, with the seasons defined as follows:

Spring	March – May
Summer	June – August
Autumn	September – November
Winter	December – February

3.2 Wind Data

3.2.1 Definitions

Wind speed, unless otherwise specified, has been converted from anemometer height to an equivalent ten-meter height assuming neutral stability and is designated U_{10}. Details of this conversion are covered in Section 3.2.2.

Tabulated wind direction is the direction toward which the wind is blowing, expressed in degrees from true north. When plotted, the arrows representing wind direction follow this convention and point downwind.

3.2.2 Data Preparation

The four stations providing wind speed and direction have anemometers at the following heights:

Station	Anemometer Height
Buoy 44004	5.0 m
Buoy 44008	5.0 m
Buoy 44011	5.0 m
Buzzards Bay Tower	43.3 m

The wind speed measured at the instrument height is designated as U_z. The algorithm for conversion to ten-meter reference height, U_{10}, assumes a neutral air column. We can then express U_z in terms of von Karman's constant, κ, the friction velocity, u_*, height in meters, z, and roughness height, z_0,

$$U_z = 1/\kappa\, u_* \ln \frac{z}{z_0} \tag{9}$$

where the friction velocity is related to the ten-meter wind speed through

$$u_* = \sqrt{C_{d10}}\, U_{10} \tag{10}$$

and $\kappa = 0.4$. Empirical values of the drag coefficient C_{d10} are given by Janssen et al. (1987)

$$C_{d10} = \begin{cases} (0.8 + 0.065U_{10}) \times 10^{-3} & U_{10} \geq 7.5\, m/s \\ 1.2875 \times 10^{-3} & U_{10} < 7.5\, m/s \end{cases} \tag{11}$$

To eliminate the unknown z_0, write one equation for the measured U_z and one for the desired U_{10} in the following form,

$$U_z = 1/\kappa\, u_* \ln z - 1/\kappa\, u_* \ln z_0 \tag{12}$$

$$U_{10} = 1/\kappa\, u_* \ln 10 - 1/\kappa\, u_* \ln z_0 \tag{13}$$

and subtract to give,

$$U_z - U_{10} = 1/\kappa\, u_* \ln \frac{z}{10} \tag{14}$$

Substituting (10) for u_* and rearranging gives

$$U_{10} = \frac{U_z}{1/\kappa \sqrt{C_{d10}} \ln \frac{z}{10} + 1} \tag{15}$$

This is non-linear (C_{d10} is a function of U_{10}) and is iterated to solve for U_{10}. Instead of iterating until a convergence criterion is met, a simplified two-step procedure produced errors of less than $0.1\, m/s$ over the full range of wind speeds. The procedure used here is detailed below:

Step 1: Take a first estimate of U_{10} as $U_{43.3} \times 0.83$ or $U_5 \times 1.1$. These coefficients are found to give an acceptable first approximation.

Step 2: Using this value of U_{10}, find C_{d10} using Equation 11.

Step 3: Refine U_{10} using (15) with the new value of C_{d10}.

Step 4: Refine C_{d10} using (11).

Step 5: Find final value of U_{10} using (15).

Wind speed is treated as a scalar for some presentations. In these cases, the mean, mode, median and standard deviation are calculated in the same way as the scalar wave quantities, described in Section 3.1.2.

There are two mean wind directions calculated, an unweighted mean based only upon wind direction, and a mean with directions weighted by the corresponding wind speeds.

The unweighted mean direction is given by

$$\bar{\theta}_{unweighted} = \arctan\{ \frac{\sum_{i=1}^{N} \sin\theta_i}{\sum_{i=1}^{N} \cos\theta_i} \} \tag{16}$$

where θ_i is the wind direction in degrees from true north of the i'th of N measurements.

The weighted mean direction and speed are given by

$$\bar{\theta}_{weighted} = \arctan\{\frac{\sum_{i=1}^{N} U_i \sin\theta_i}{\sum_{i=1}^{N} U_i \cos\theta_i}\} \tag{17}$$

$$\bar{U}_{weighted} = \frac{1}{N}\sqrt{(\sum_{i=1}^{N} U_i \sin\theta_i)^2 + (\sum_{i=1}^{N} U_i \cos\theta_i)^2} \tag{18}$$

where U_i is the wind speed of the i'th measurement.

3.2.3 Presentation

Ten-meter wind speed, U_{10} is plotted as hourly time series in a bar graph format with each plot covering one month. The wind velocity field is plotted as a feather diagram, with vectors originating at four hour intervals along the time axis and pointing in the downwind direction with length equal to U_{10}.

Two histograms are also presented. The first plots the percentage of wind speeds in each bin of width $0.1m/s$. The other plot is a rose plot or a circular histogram showing the percentage of wind directions in each bin of width 10 degrees. This plot also shows station name and month.

Summaries of wind speed and direction are presented in tabular form. The first section of the table for each station shows the minimum speed, mean speed, maximum speed, mean weighted direction and mean unweighted direction for each month. The second part of the table is similar but displays the information over seasons, not months, with seasons defined as in Section 3.1.3.

4 Wave Height Extreme Value Analysis

4.1 Overview

Estimates of significant wave height five and ten year return values, H_{s5} and H_{s10}, were obtained for each of the four buoys by fitting a Fisher-Tippett Type 1 distribution to the observed distributions of H_s and extrapolating to the required probabilities.

In using extreme value analysis to predict extreme wave heights, it is customary to forecast a 50 or 100 year maximum. The short length of our record, 18 months, precluded forecasting these long return periods but supported the shorter intervals.

4.2 Sampling and Preparation Methods

Extreme value analysis is most easily applied to a series of maximum values taken from fixed time periods of equal length. We used the monthly maxima. The analysis assumes that these data are independent realizations of identically distributed random variables. This requires special preparation because wave heights from different calendar months are not identically distributed. We assume two properties of the distributions:

- Wave heights from different calendar months have different distributions. There is a seasonal trend with a period of one year.
- Wave heights from the same calendar month in different years are from the same distribution.

In order to prepare the data it was necessary to remove the deterministic trend. This was done in two steps. The 18 months of data were reduced to twelve calendar months by combining the data from the same months in different years. The data were then normalized to approximate identical distributions by dividing the maximum significant wave height from each month by the mean of all significant wave heights for that month. While the distribution of significant wave heights is too complicated to normalize by the mean alone, this is a useful first approximation. It is worthwhile to note that Rayleigh distributions may be completely normalized using this technique. A thorough review of extreme value analysis of wave heights is provided by Muir (1986).

4.3 Selection of the Extreme Value Distribution

We selected the Fisher-Tippett Type 1 as the appropriate extreme value distribution. The domain of attraction of an extreme value distribution is the collection of all distributions which have that extreme value distribution as their limiting type. The Fisher-Tippett Type 1 distribution has as its domain of attraction the distributions for which all positive moments exist. This includes the Rayleigh, Weibull, normal and lognormal distributions. Since wave heights are always positive and finite, this distribution is therefore an appropriate choice.

The Fisher-Tippett Type 1 distribution is defined by its cumulative distribution function:

$$P_N = \text{Prob}(H_s < H_{SN}) = \exp\{-\exp[-(H_{SN} - A)/B]\} \tag{19}$$

$$H_{SN} = A + B\{-\ln[-\ln P_N]\} \tag{20}$$

Here, A is a location parameter and B is a scale parameter. H_{SN} is the N year extreme value significant wave height and P_N is the probability associated with the N year return period.

The mean, μ, and variance, σ^2, of this distribution are given by

$$\mu = A + \gamma B \tag{21}$$

$$\gamma = 0.5772\cdots \tag{22}$$

$$\sigma^2 = \pi^2 B^2/6 \tag{23}$$

4.4 Fitting the Distribution

The distribution was fit to the data sets using a combination of two methods, the method of moments and maximum likelihood estimation. These and other fitting methods are described in detail by Carter and Challenor (1983).

The method of moments solves for the estimators $\hat{A}$ and $\hat{B}$ by using the sample mean $\bar{x}$ and sample variance from (21) and (23) above. The estimators are:

$$\hat{B} = \frac{\sqrt{6}}{\pi}\sqrt{\frac{\sum[x_i - \bar{x}]^2}{n-1}} \tag{24}$$

$$\hat{A} = \bar{x} - \gamma\hat{B} \tag{25}$$

where $x_i (i = 1, n)$ are the sample values.

Maximum likelihood estimators are obtained by solving the following system of maximum likelihood equations:

$$\sum_{i=1}^{n} \exp\left[-(x_i - \hat{A})/\hat{B}\right] - n = 0 \tag{26}$$

$$\sum_{i=1}^{n} (x_i - \hat{A})\left\{1 - \exp\left[-(x_i - \hat{A})/\hat{B}\right]\right\} - n\hat{B} = 0 \tag{27}$$

The iterative scheme we used combines the methods as follows:

Step 1: Use the method of moments to solve for starting values of the estimators.

Step 2: Solve (26) three times using $\hat{A}$ and the perturbed values $\hat{A} + \Delta$ and $\hat{A} - \Delta$ where Δ is initially assigned the value 0.01. Find the equation with the smallest error and update the value of $\hat{A}$ if necessary.

Step 3: Repeat step 2 using (27) and perturbed values of $\hat{B}$.

Step 4: Repeat steps 2 & 3 until unperturbed values of both estimators give the smallest errors. This procedure changes each parameter with a fixed step size until the errors in (26) and (27) are minimized.

Step 5: Divide Δ by 10.

Step 6: Repeat steps 2 through 5 until until $\Delta < 0.0001$.

4.5 Extrapolating to Predict Maxima

The procedure described above will give the Fisher-Tippett Type 1 distributions of the normalized significant wave heights for each station. The probabilities associated with five and ten year return periods are

$$P_5 = 1 - \frac{1}{5 \times 12} = 0.98333 \tag{28}$$

$$P_{10} = 1 - \frac{1}{10 \times 12} = 0.99167 \tag{29}$$

These probabilities are used in (20) to solve for a five and ten year extreme normalized significant wave height for each buoy. The normalized height is then multiplied by each monthly mean to give a five and ten year extreme wave height for each month for each buoy. These mean, five and ten year expected maxima are listed for each station in Tables 18, 19, 20, and 21.

Information in the extreme value tables should be interpreted as follows. Recall that we removed the seasonal trends to reduce monthly maximum significant wave heights to a common distribution. We then predicted the five and ten year expected maxima for this normalized distribution. The maxima of the normalized distribution may occur during any month and will be associated with actual wave heights which depend on the monthly mean. For example, the extreme five year wave which might happen in March, a stormy month, would be higher than had it happened in August.

References

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[2] D. J. T. Carter and P. G. Challenor, Methods of fitting the Fisher-Tippett type 1 extreme value distribution, *Ocean Engineering, 10*, No. 3, 191–199, 1983

[3] P. Janssen, G. J. Komen and W. De Voogt, Friction velocity scaling in wind wave generation, *Boundary Layer Meteorology, 38*, 29–35, 1987

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[5] J. H. Nath and R. Yeh, Some time and frequency relations in random waves, *Journal of Waterway, Port, Coastal and Ocean Engineering, 113*, No. 6, 672-683, 1987

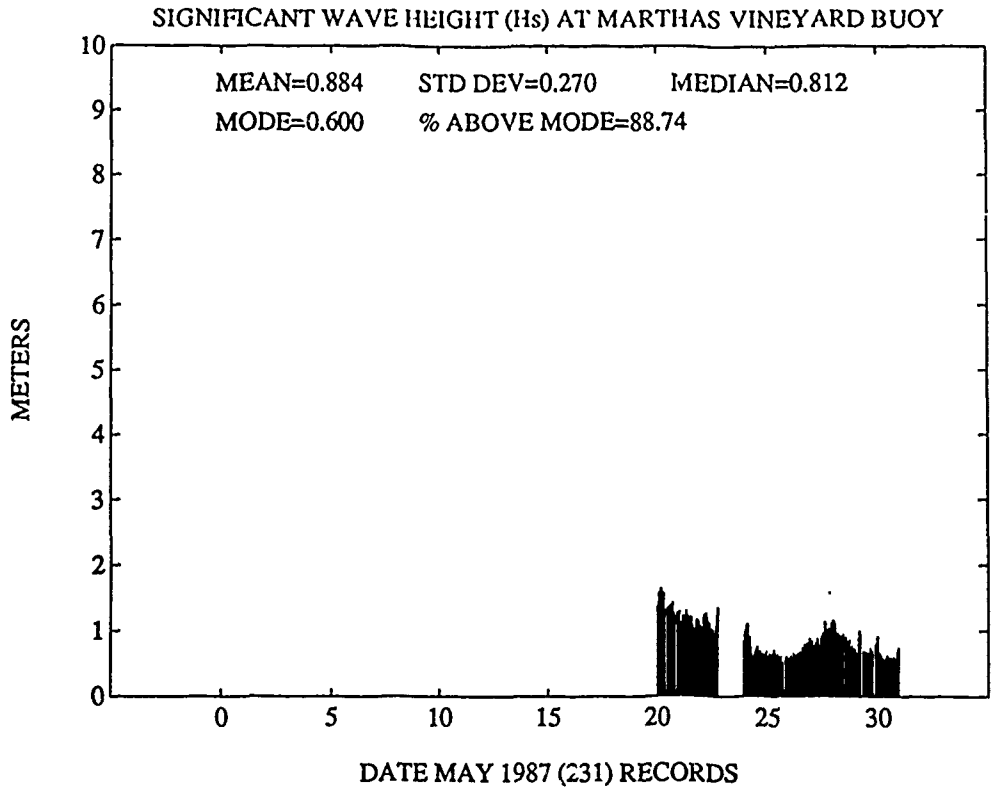
[6] National Oceanographic Data Center, *NODC Users' Guide*, Rev. 2, U.S. Dept. of Commerce, NOAA, National Environmental Satellite, Data and Information Service, 1986

[7] M. K. Ochi, Stochastic analysis and probabilistic prediction of random seas, *Advances in Hydroscience, 13*, 217–375, 1982

A Time Series Plots and Distribution Histograms

Time series plots and distribution histograms are presented in this appendix in the following sequence:

- Martha's Vineyard Buoy Wave Data
- Buzzards Bay Tower Wind Data
- Buoy 44008 Wave Data
- Buoy 44008 Wind Data



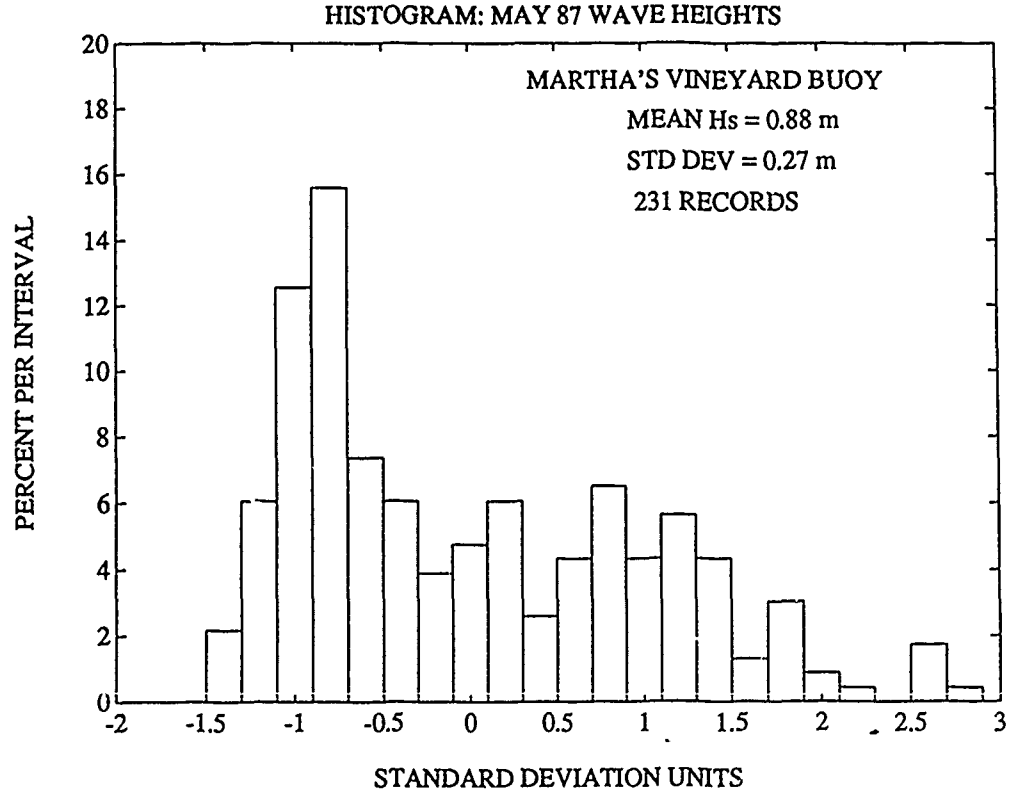
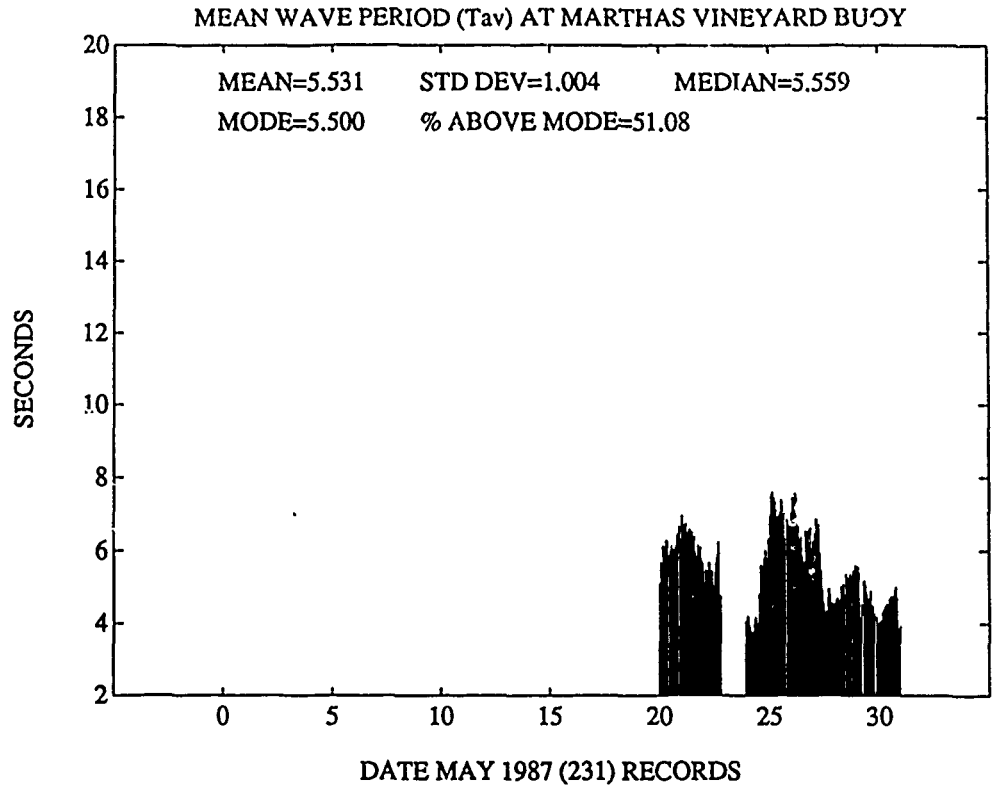


Figure 3: Wave height and period at Martha's Vineyard Buoy, May 1987. (a) Significant wave height time series, and (b) distribution.



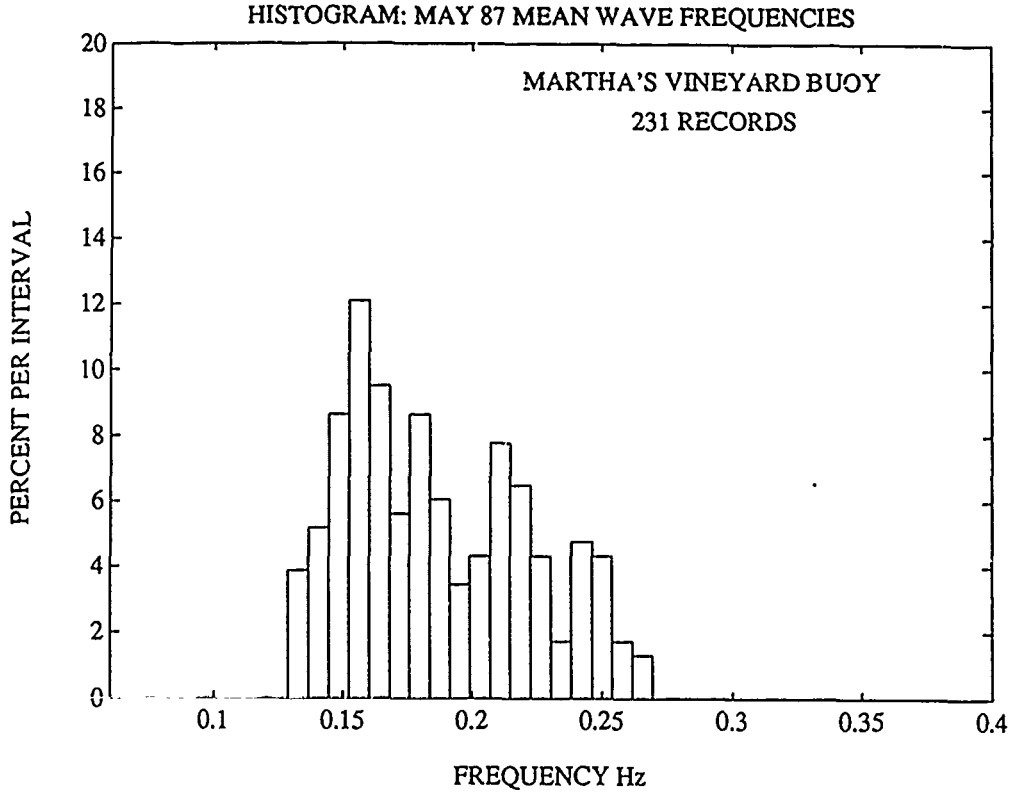
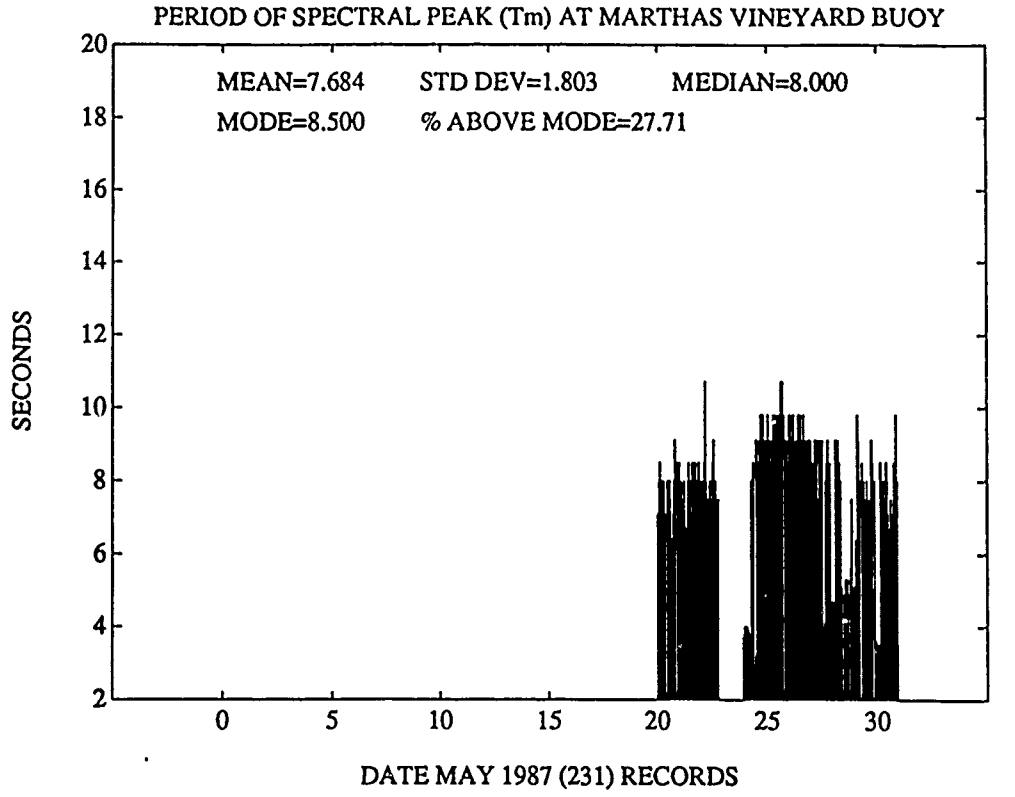


Figure 3: (continued) (c) Mean wave period time series, and (d) mean wave frequency distribution.



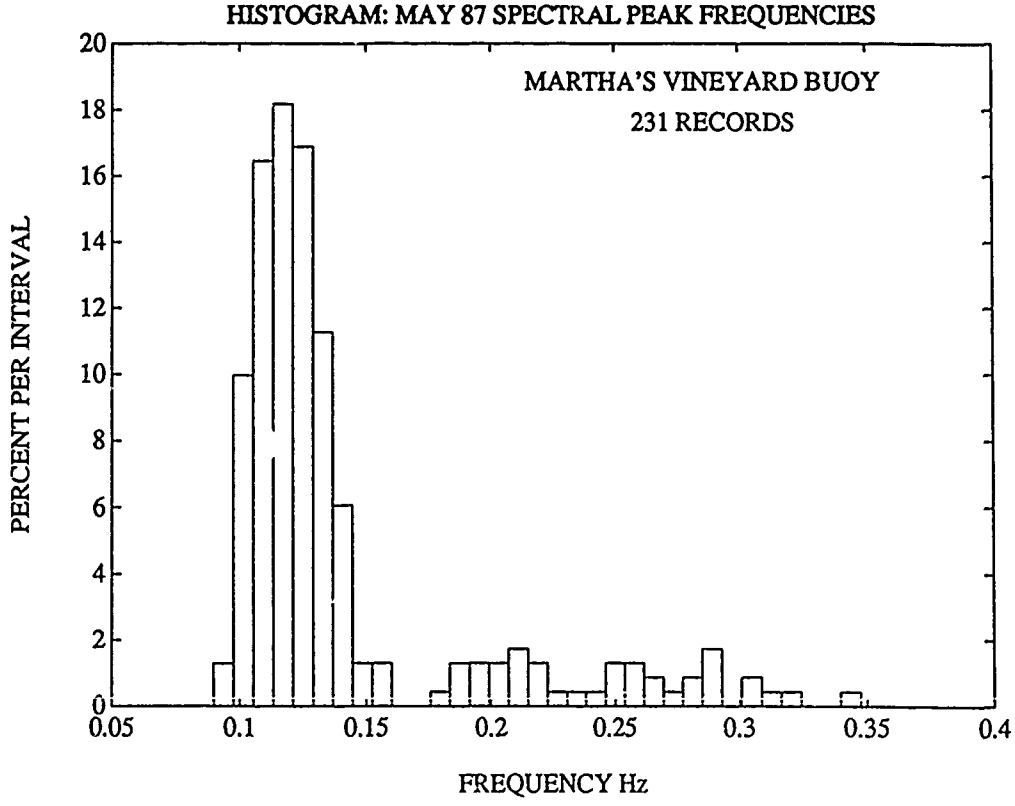
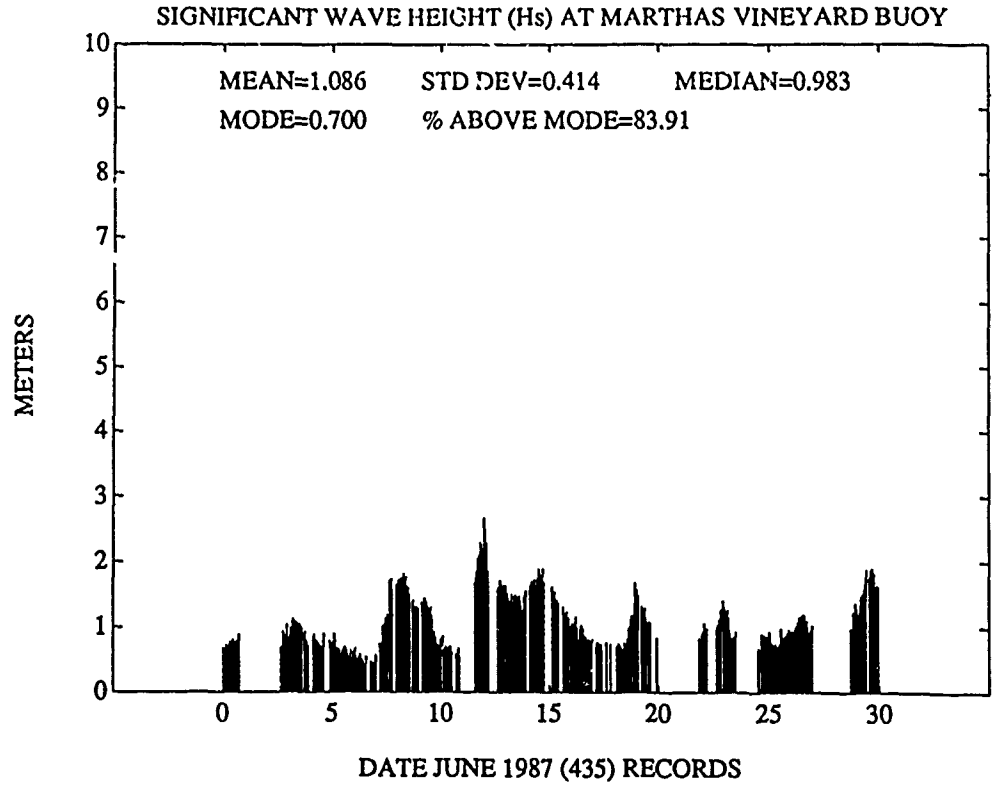


Figure 3: (continued) (e) Spectral peak period time series, and (f) spectral peak frequency distribution.



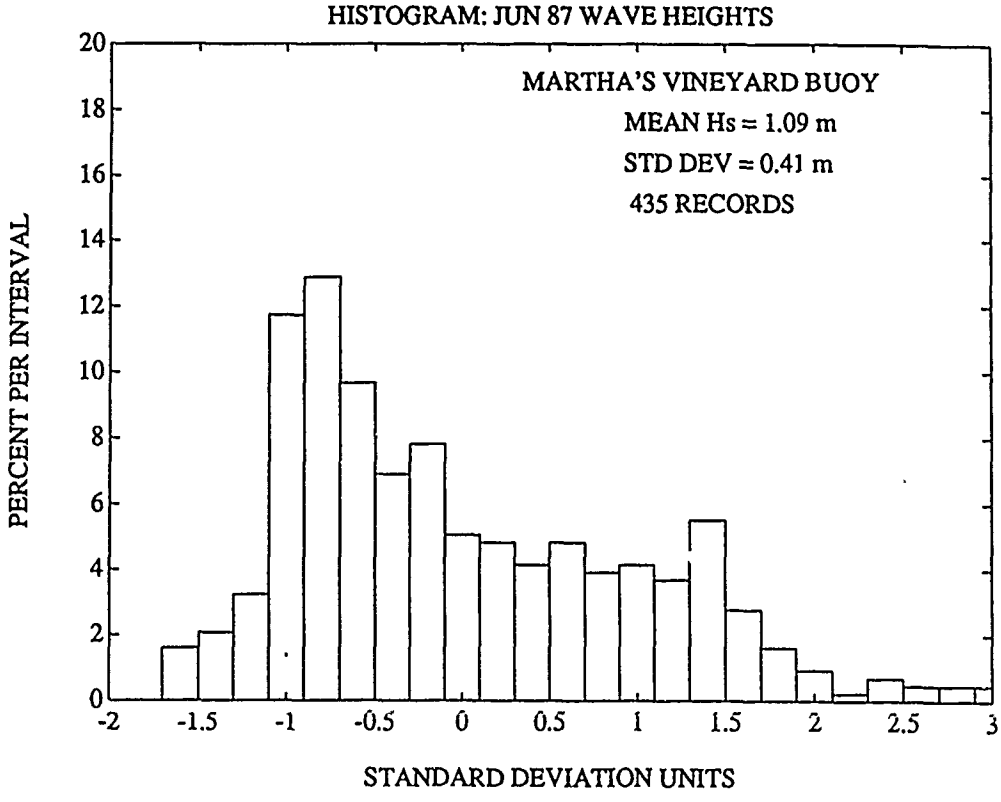
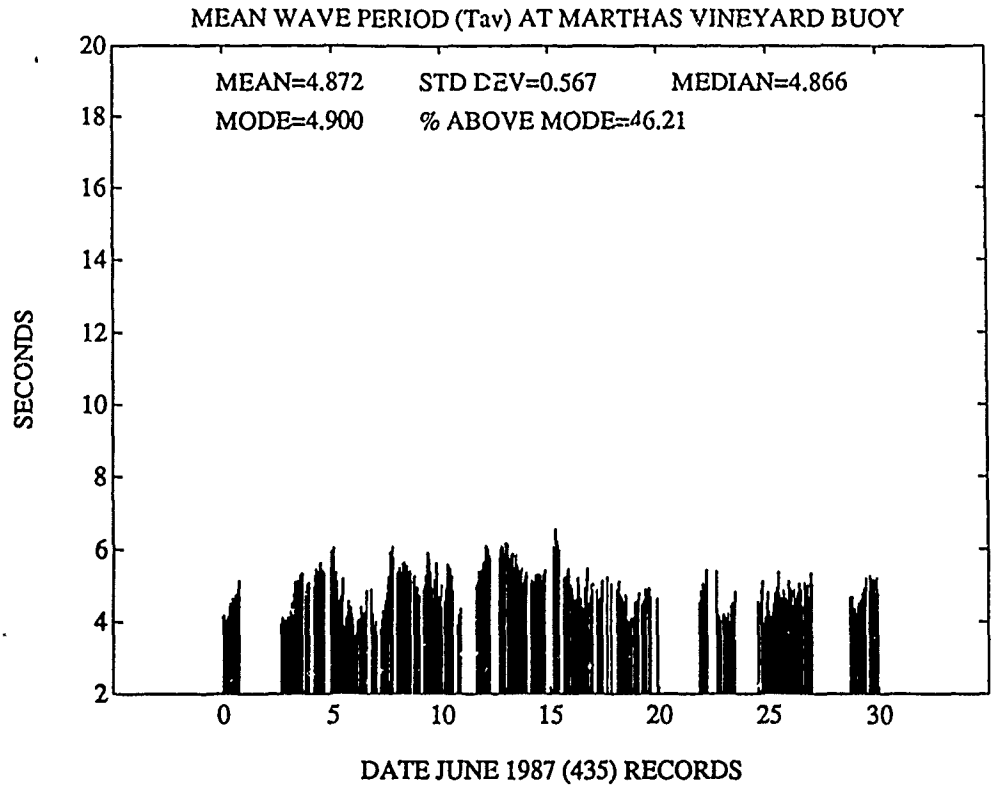


Figure 4: Wave height and period at Martha's Vineyard Buoy, June 1987. (a) Significant wave height time series, and (b) distribution.



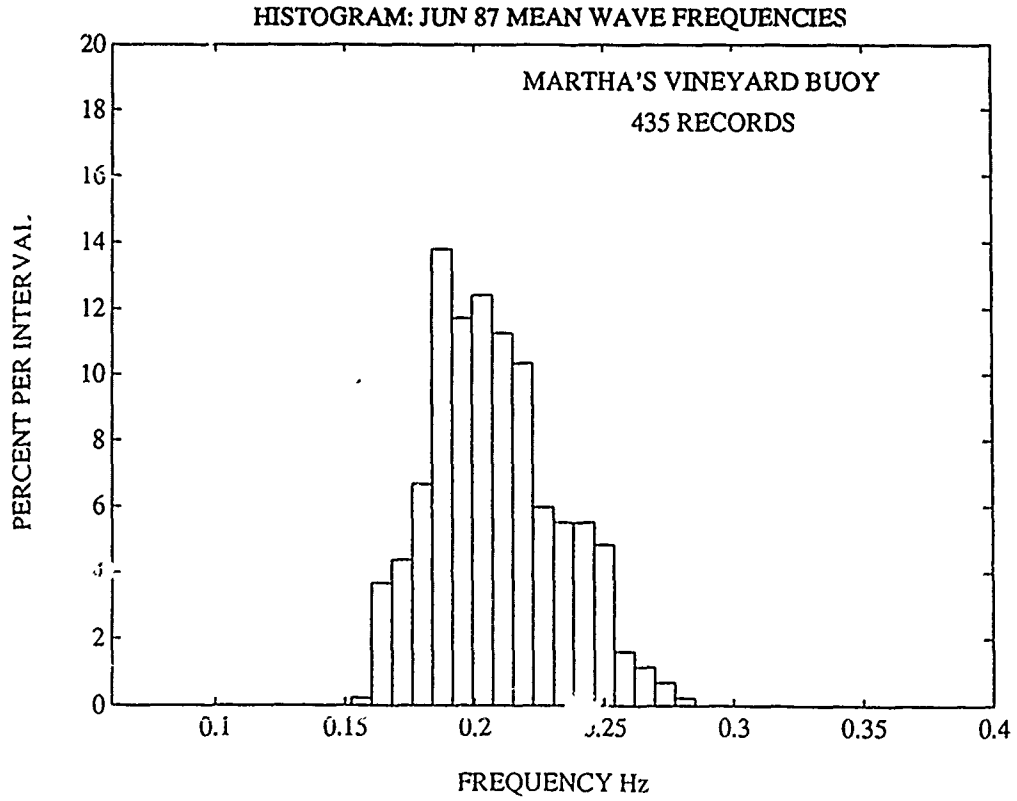
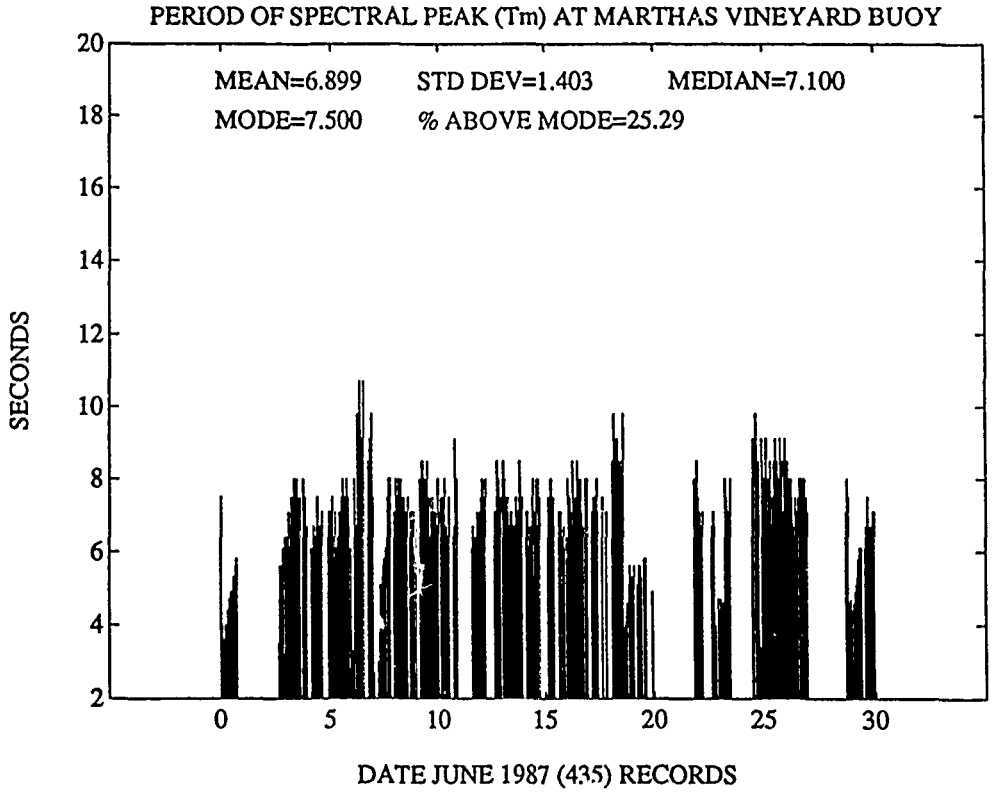


Figure 4: (continued) (c) Mean wave period time series, and (d) mean wave frequency distribution.



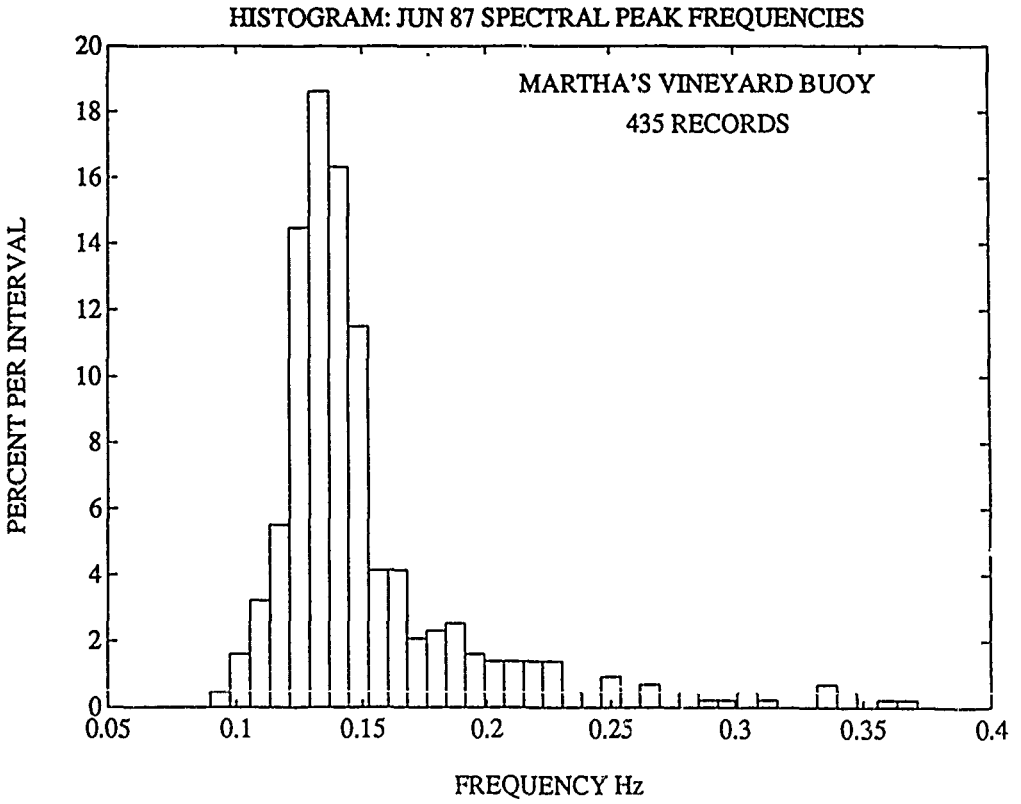


Figure 4: (continued) (e) Spectral peak period time series, and (f) spectral peak frequency distribution.

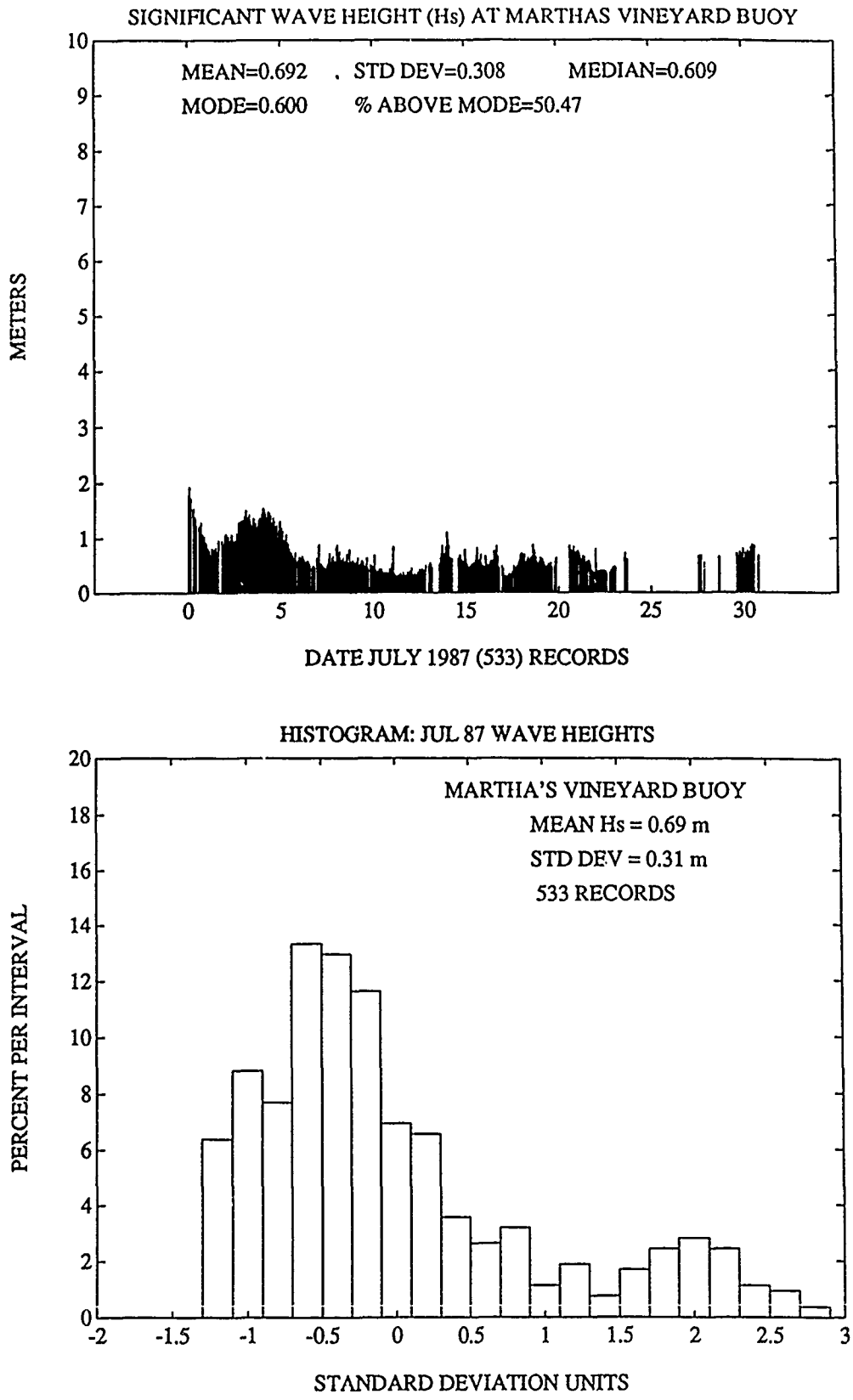
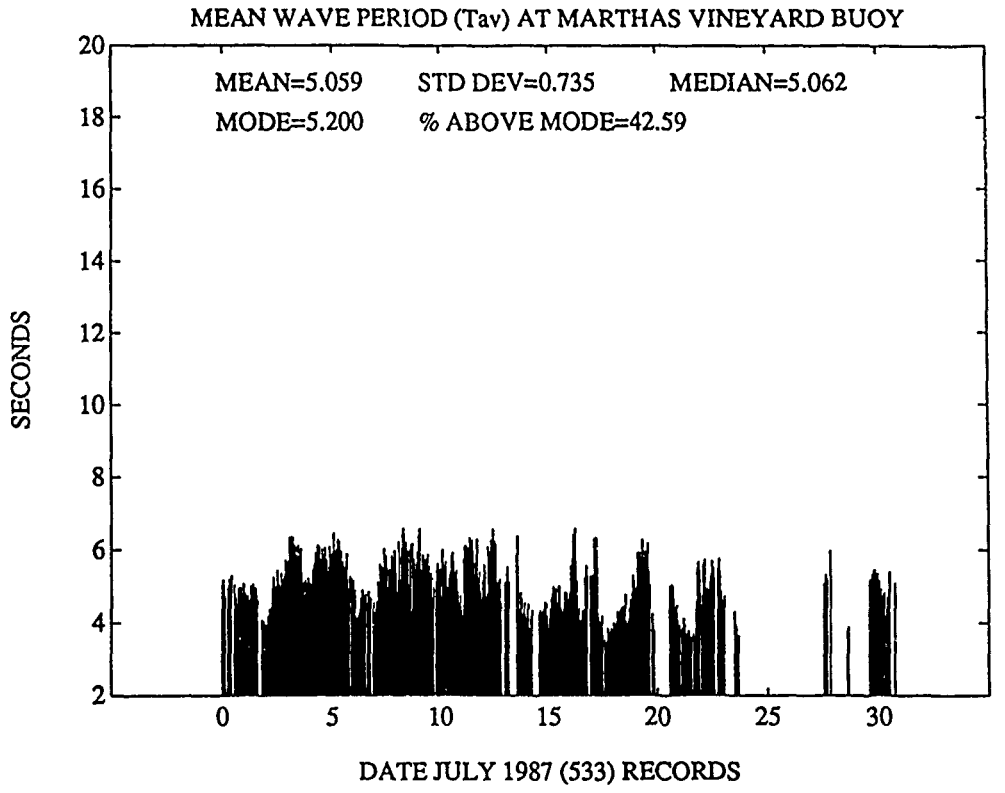


Figure 5: Wave height and period at Martha's Vineyard Buoy, July 1987. (a) Significant wave height time series, and (b) distribution.



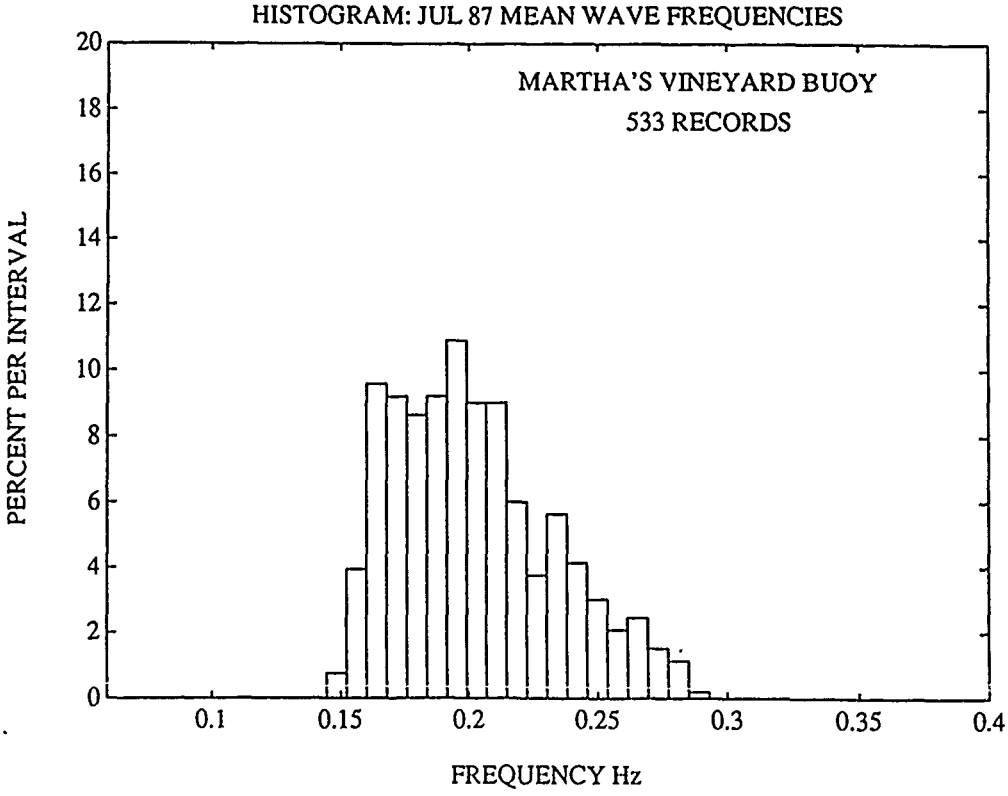
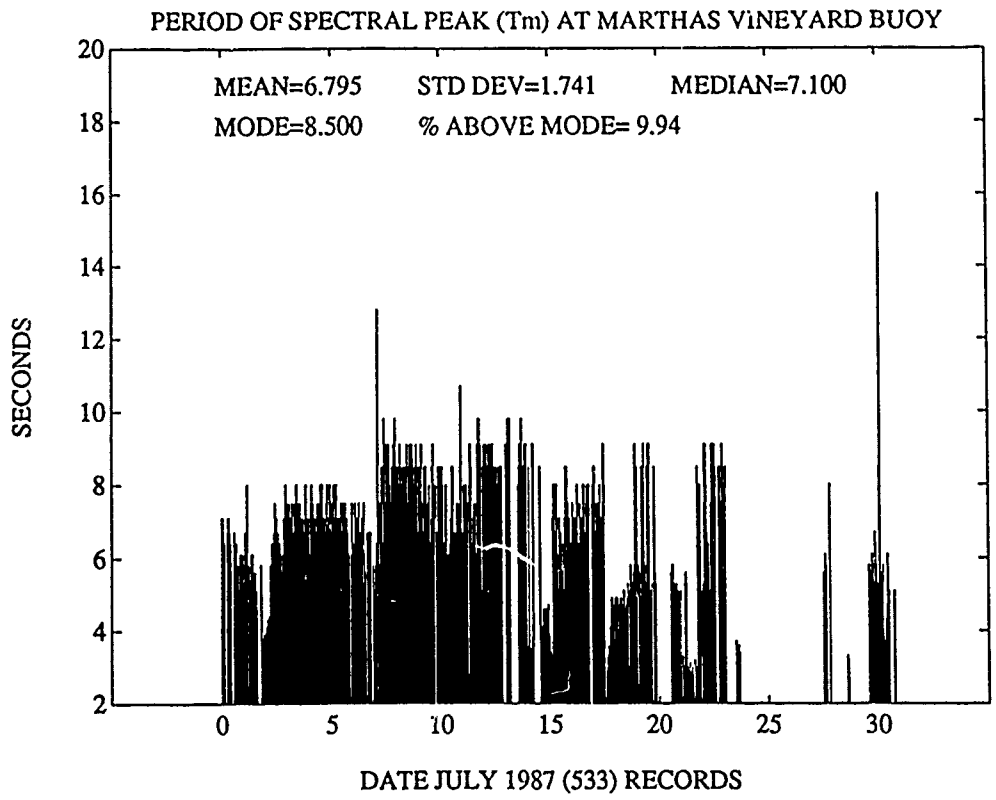


Figure 5: (continued) (c) Mean wave period time series, and (d) mean wave frequency distribution.



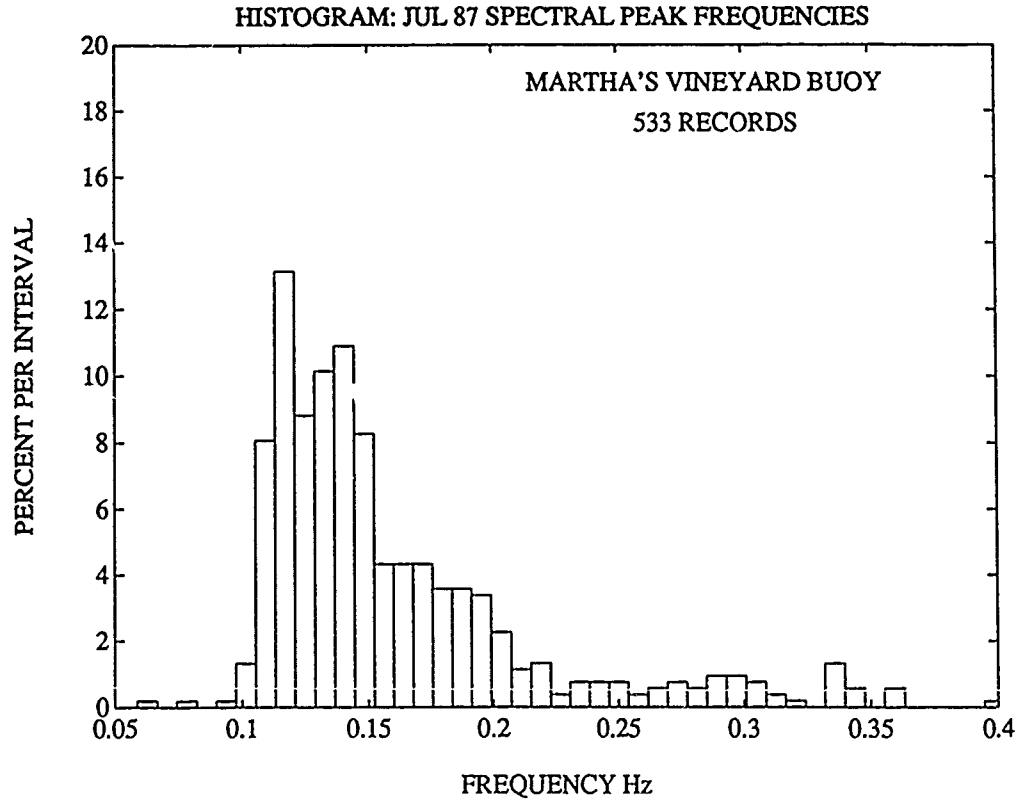


Figure 5: (continued) (e) Spectral peak period time series, and (f) spectral peak frequency distribution.

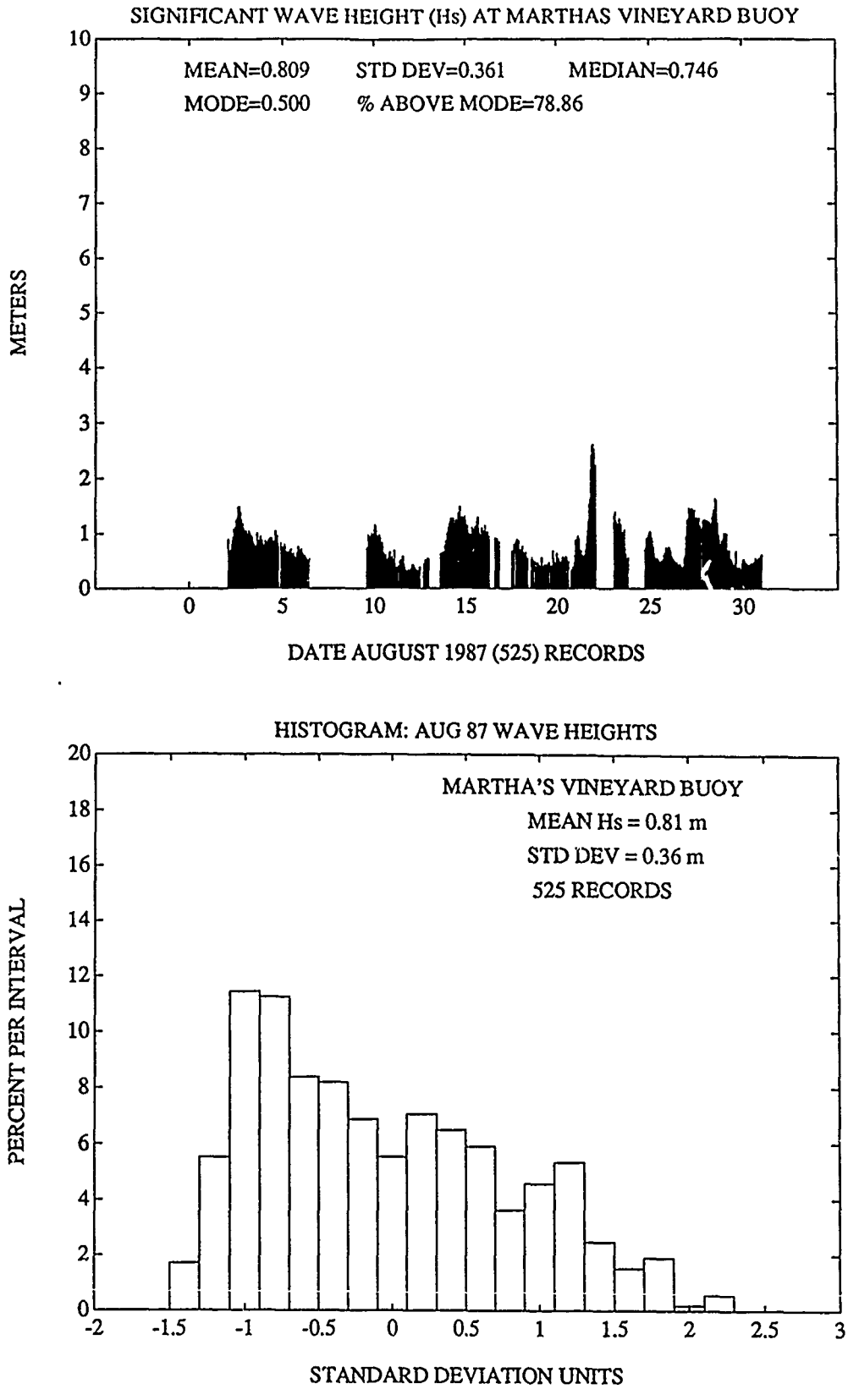
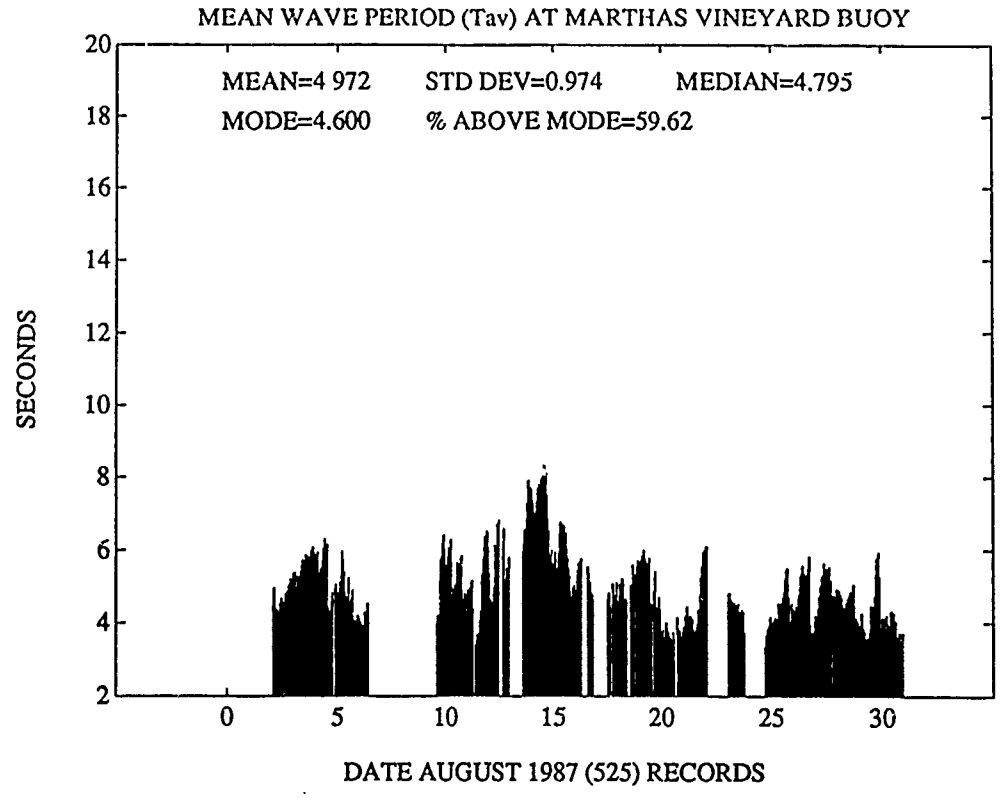


Figure 6: Wave height and period at Martha's Vineyard Buoy, August 1987. (a) Significant wave height time series, and (b) distribution.



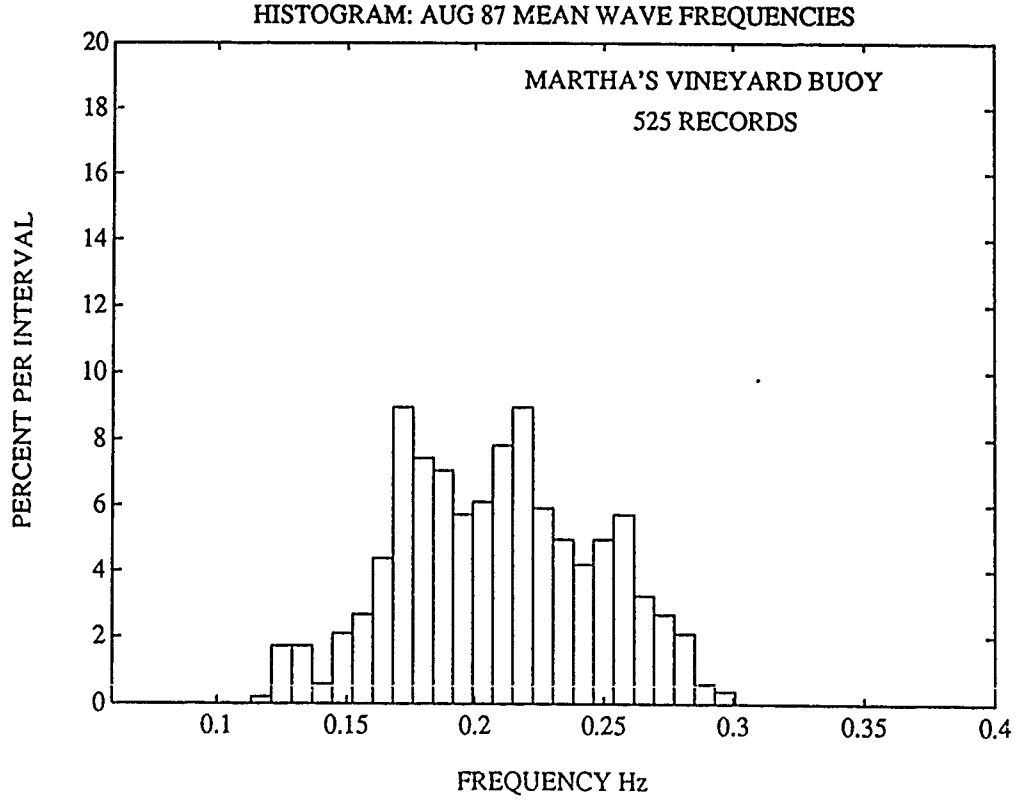
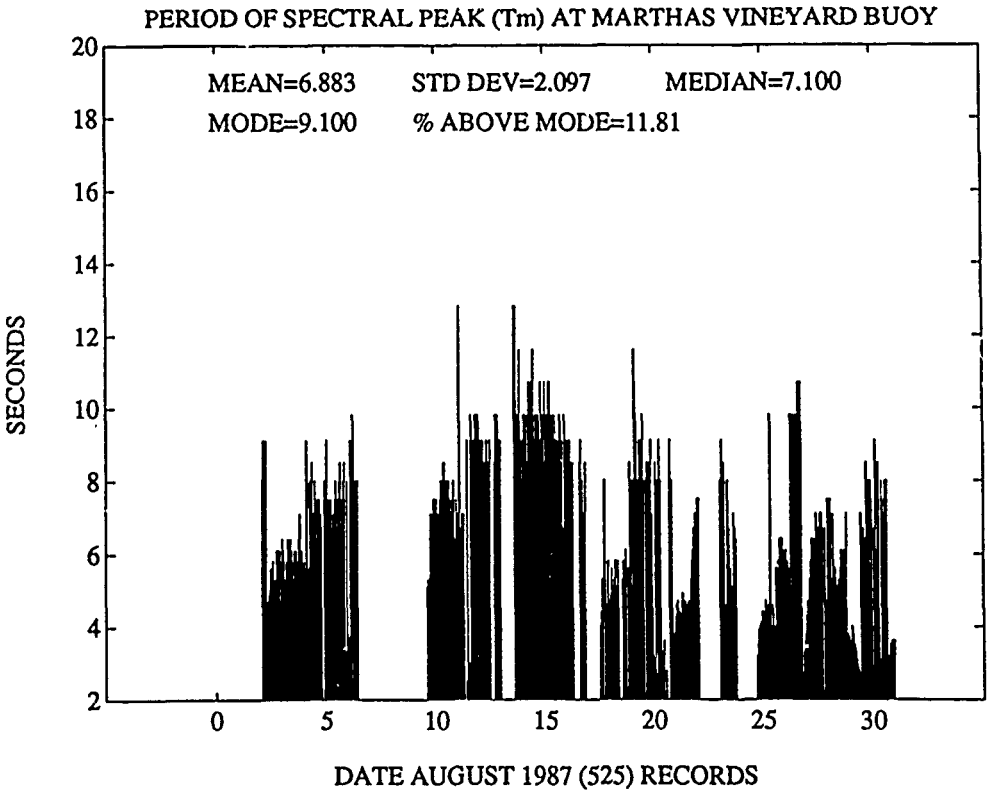


Figure 6: (continued) (c) Mean wave period time series, and (d) mean wave frequency distribution.



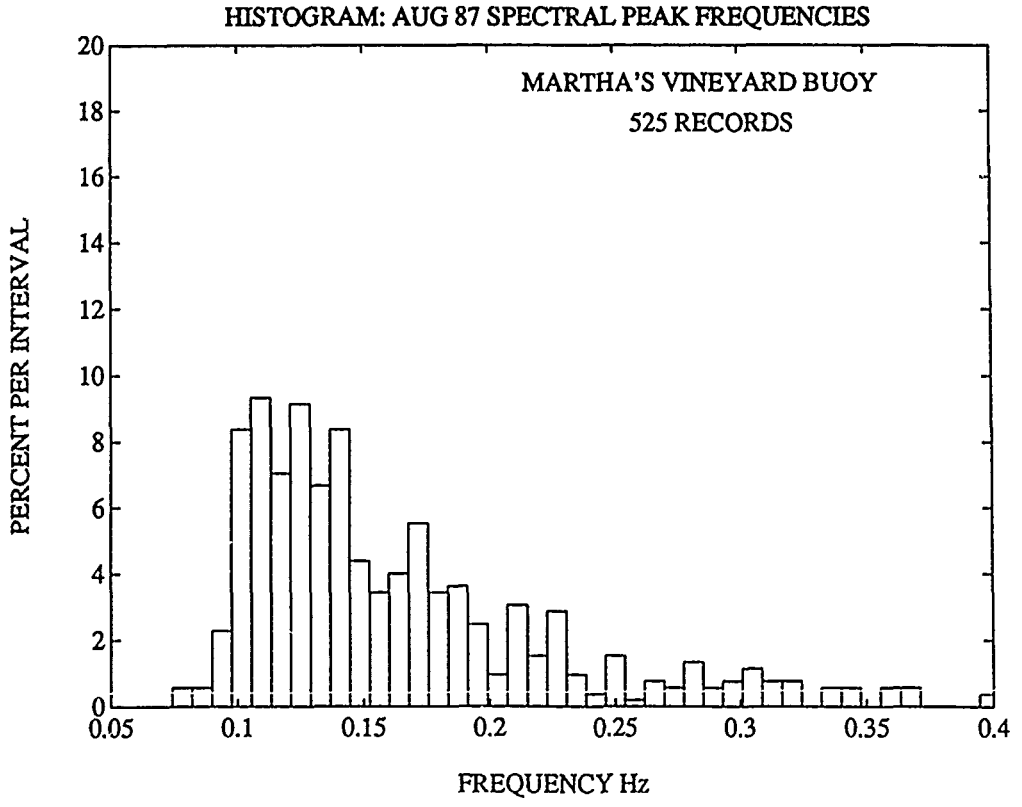


Figure 6: (continued) (e) Spectral peak period time series, and (f) spectral peak frequency distribution.

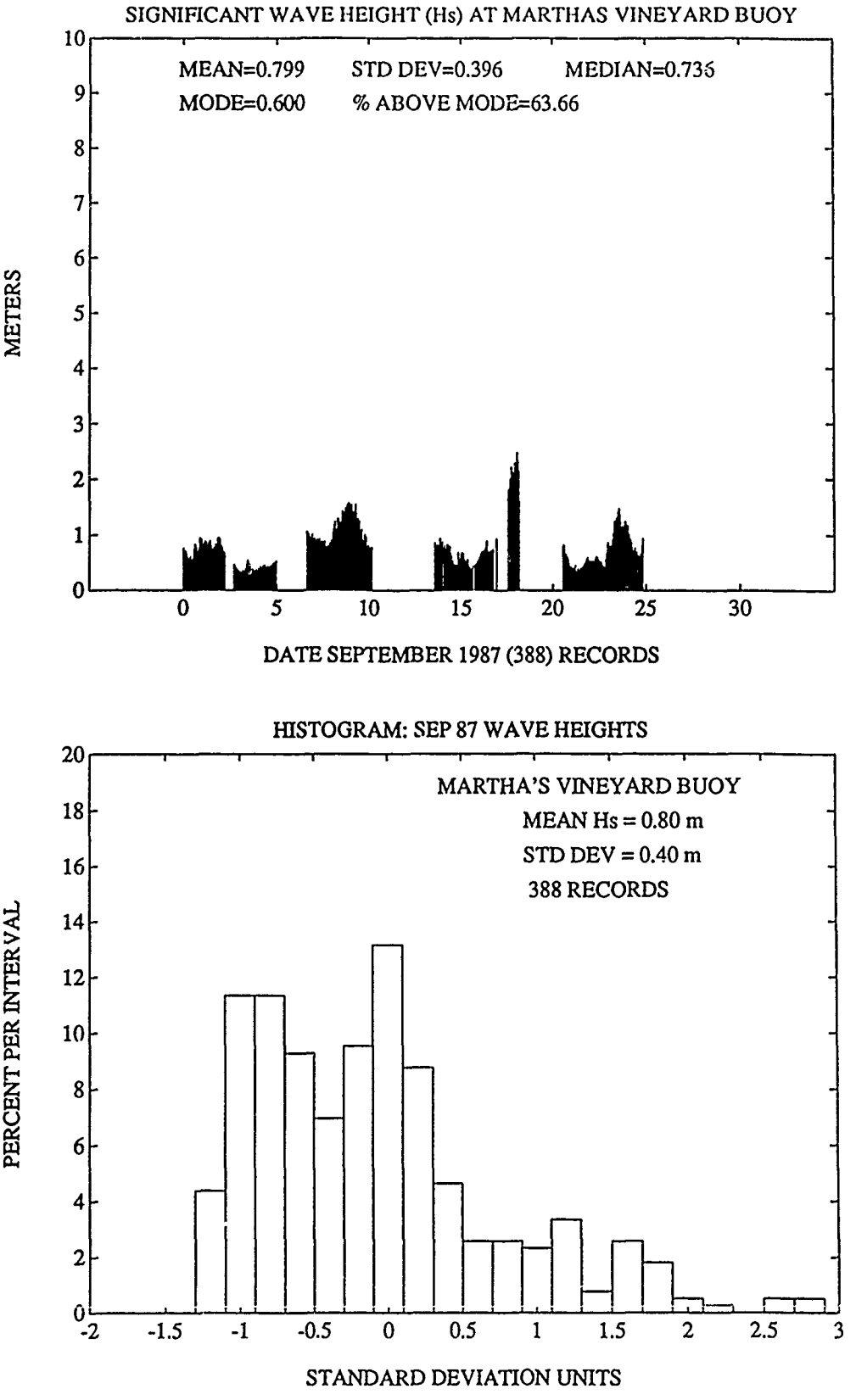


Figure 7: Wave height and period at Martha's Vineyard Buoy, September 1987. (a) Significant wave height time series, and (b) distribution.

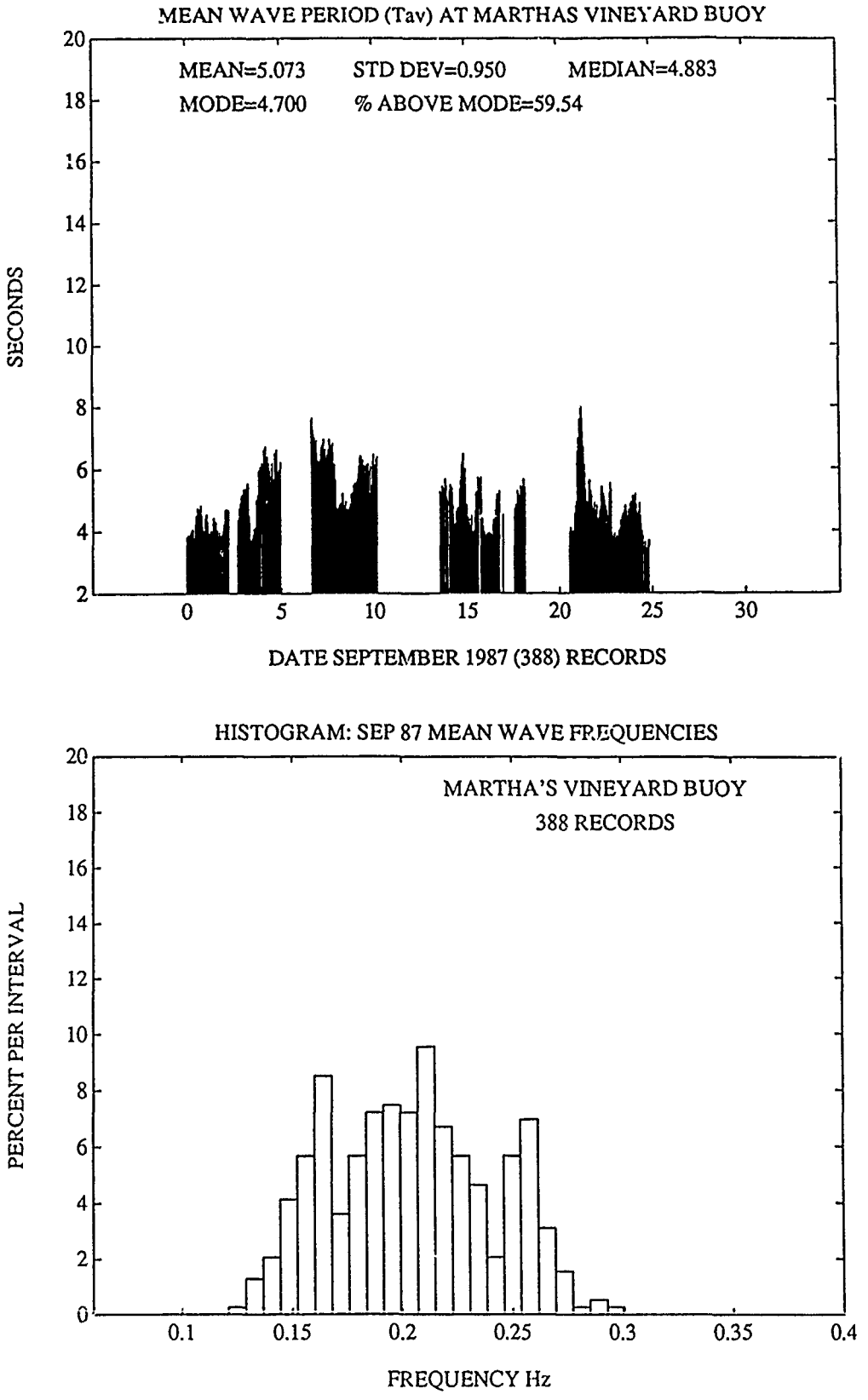
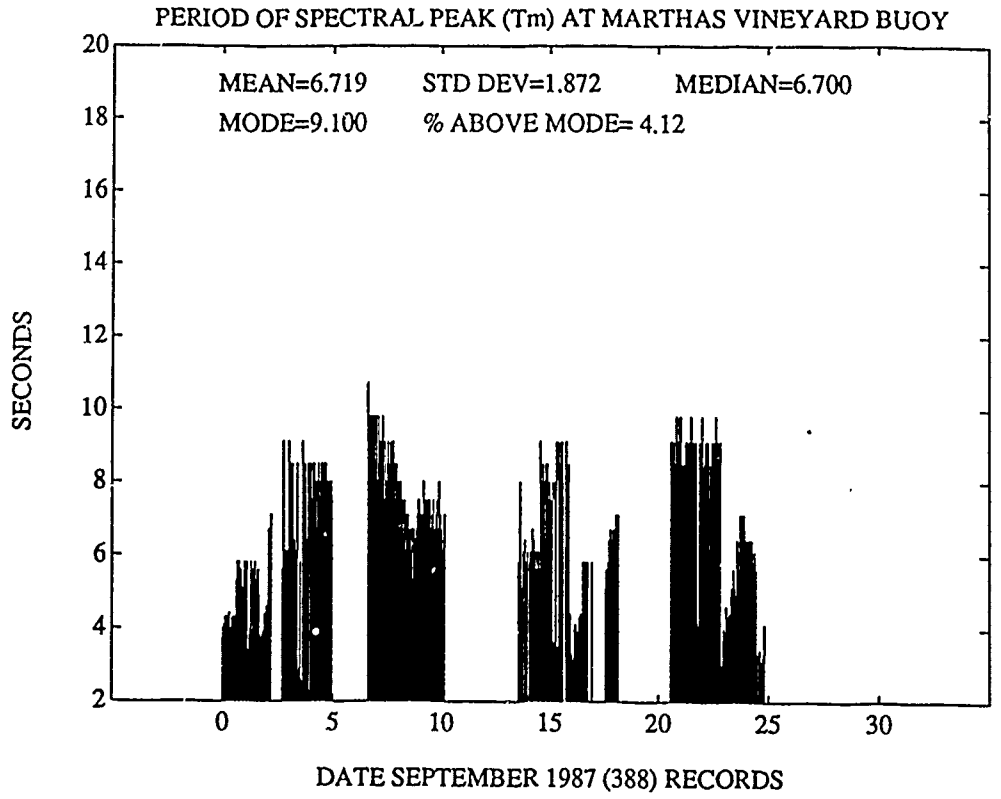


Figure 7: (continued) (c) Mean wave period time series, and (d) mean wave frequency distribution.



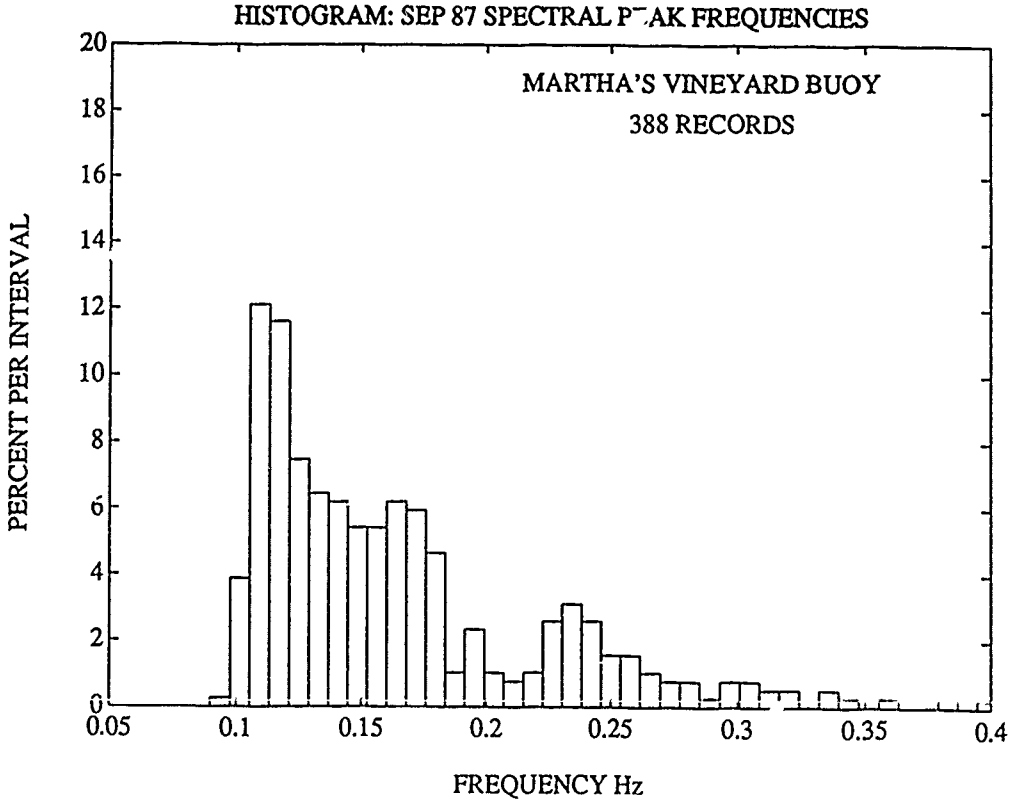


Figure 7: (continued) (e) Spectral peak period time series, and (f) spectral peak frequency distribution.

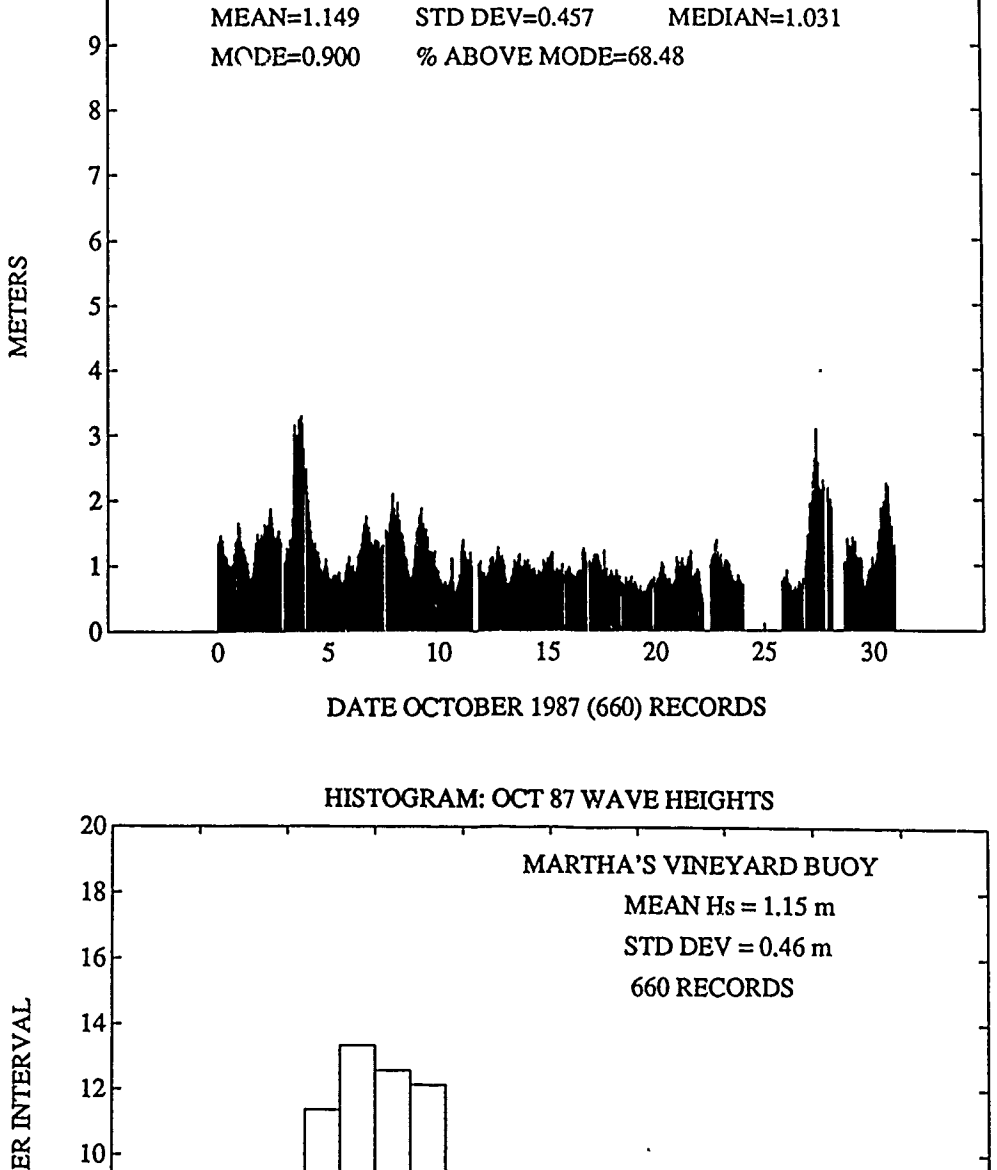


Figure 8: Wave height and period at Martha's Vineyard Buoy, October 1987. (a) Significant wave height time series, and (b) distribution.

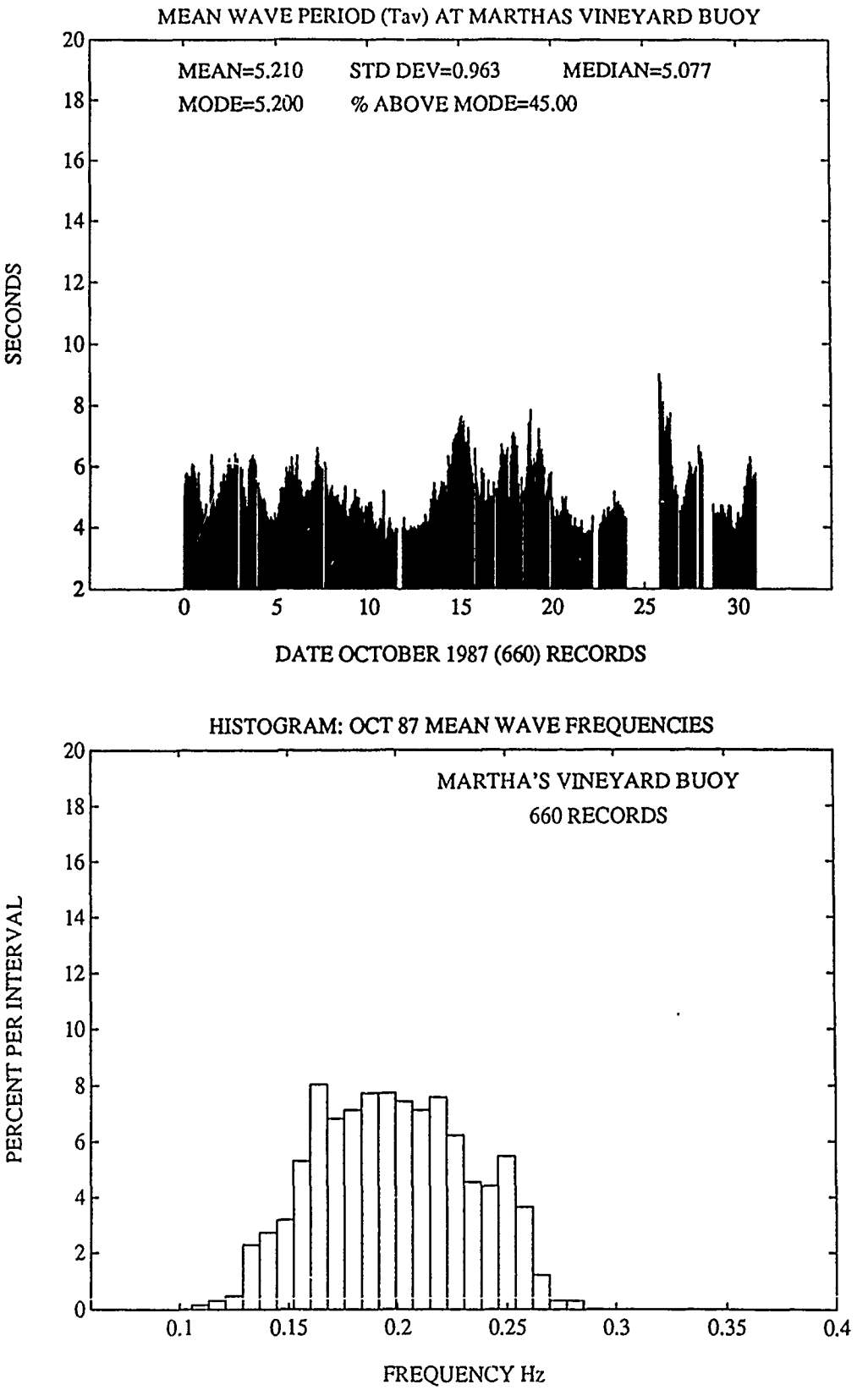


Figure 8: (continued) (c) Mean wave period time series, and (d) mean wave frequency distribution.

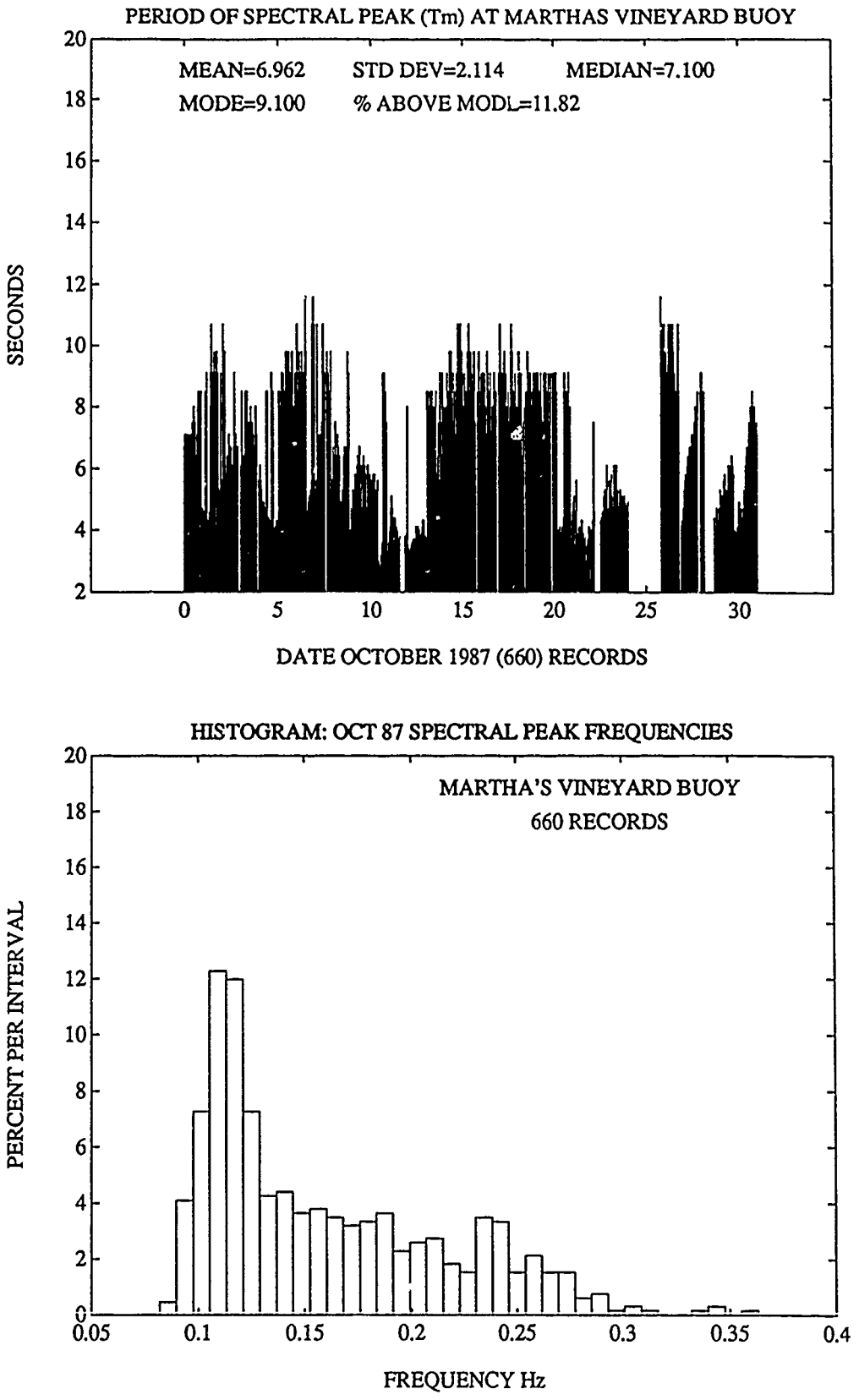


Figure 8: (continued) (e) Spectral peak period time series, and (f) spectral peak frequency distribution.

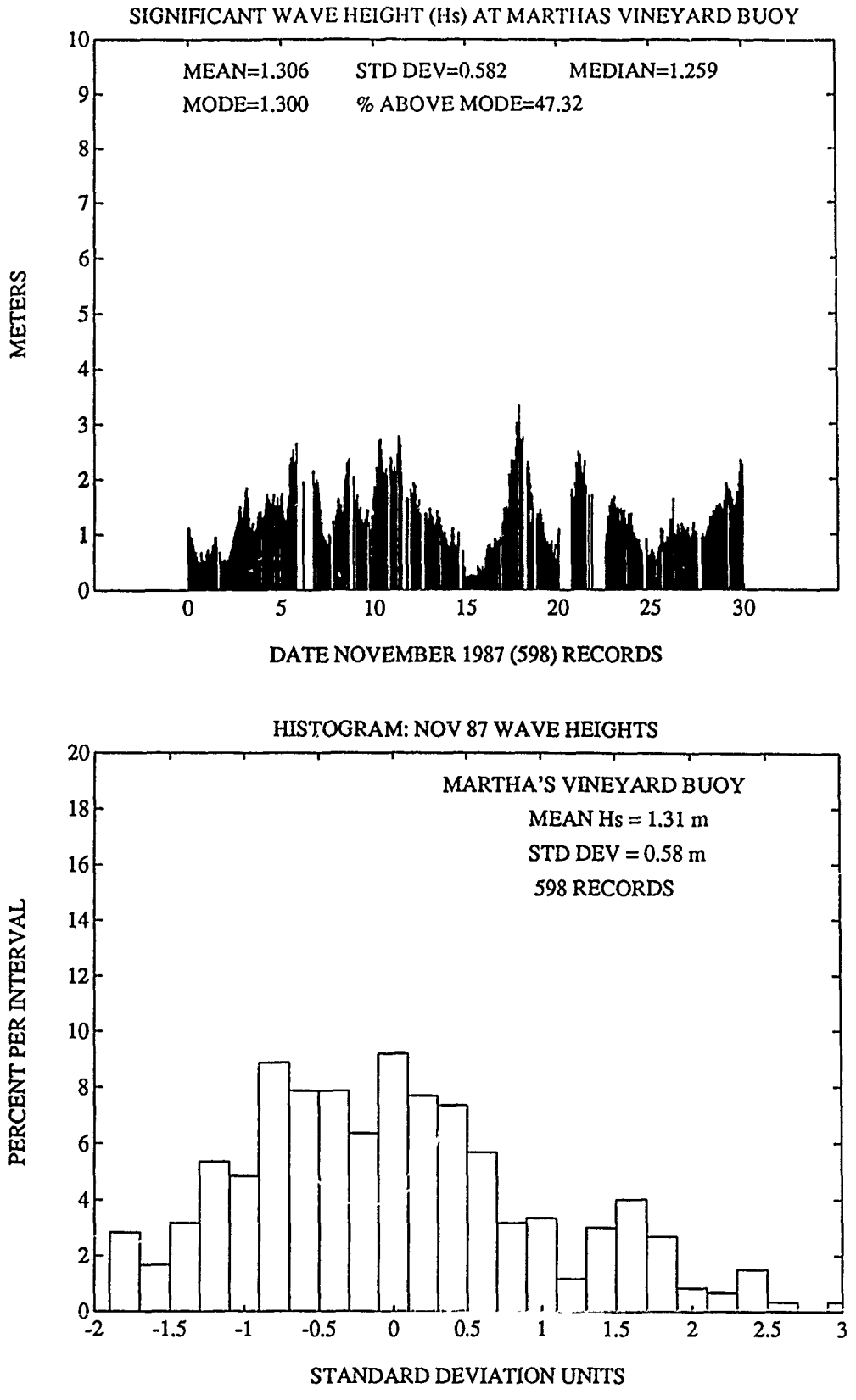
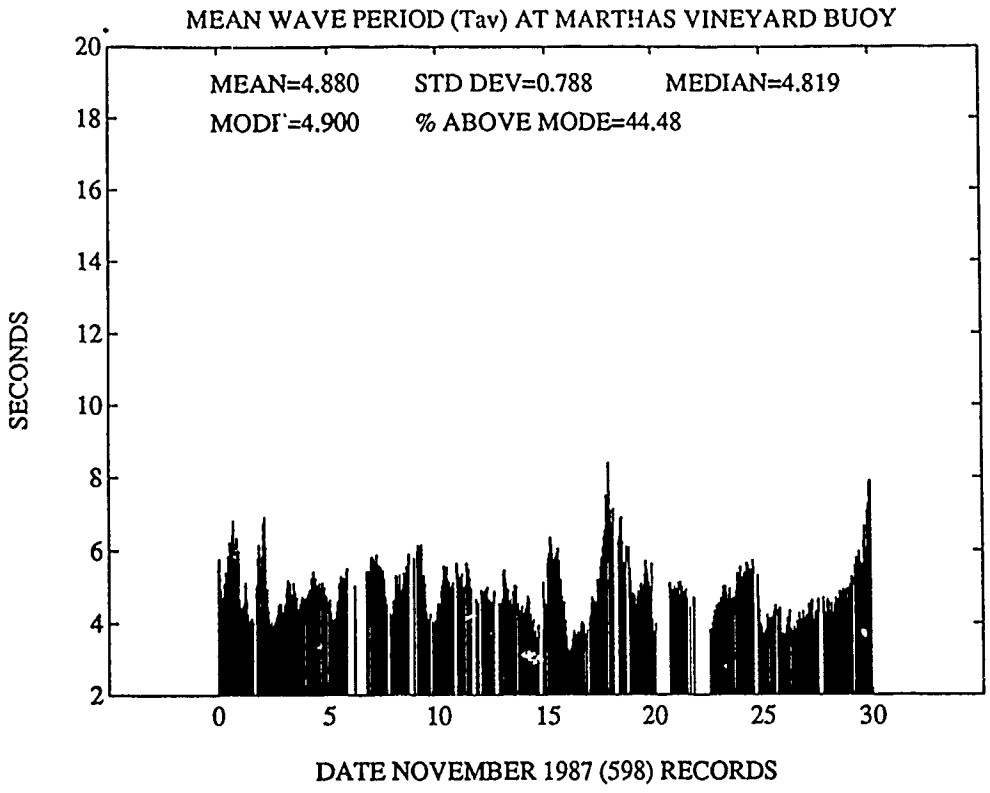


Figure 9: Wave height and period at Martha's Vineyard Buoy, November 1987. (a) Significant wave height time series, and (b) distribution.



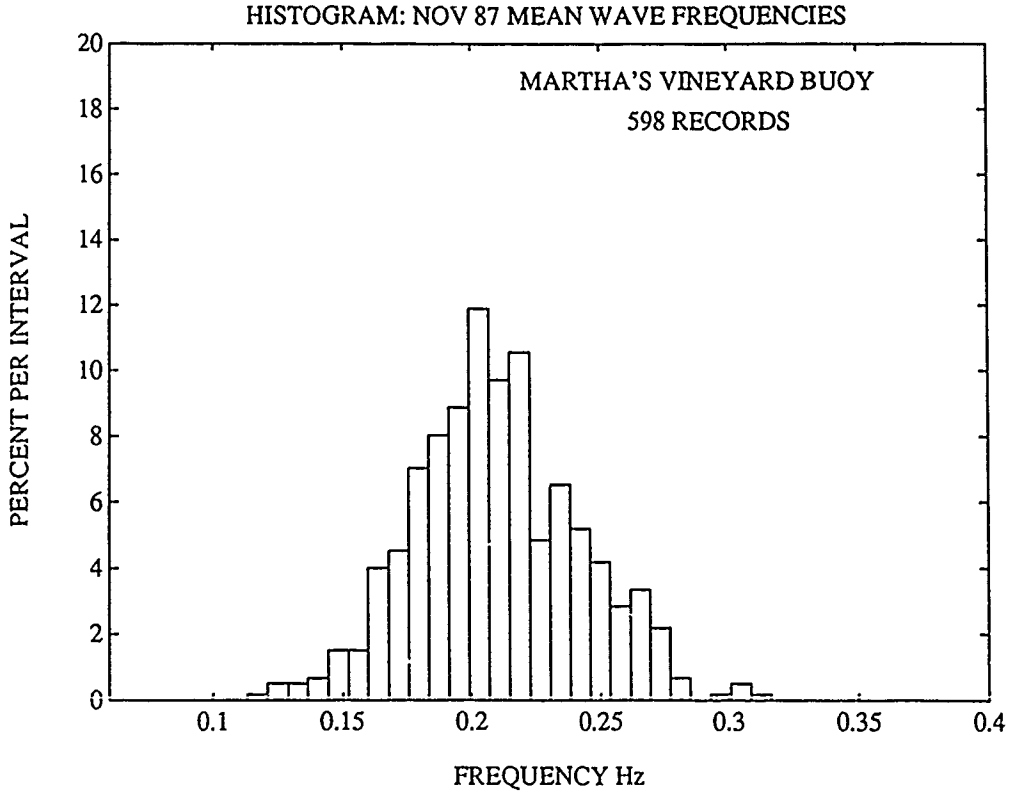
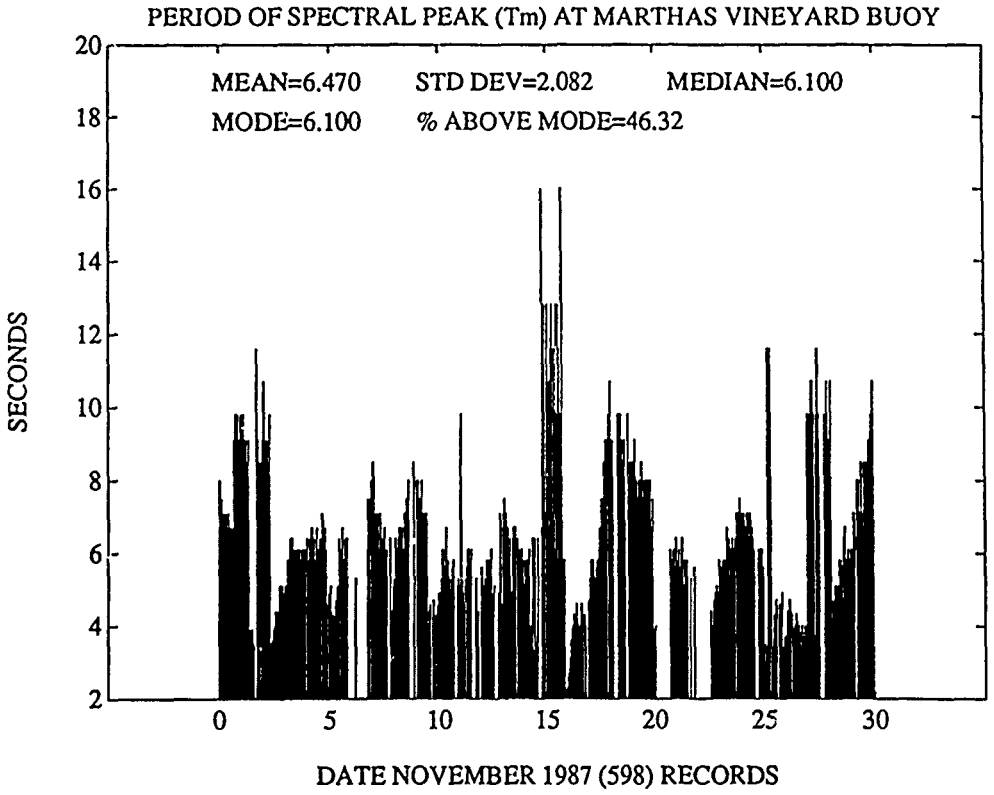


Figure 9: (continued) (c) Mean wave period time series, and (d) mean wave frequency distribution.



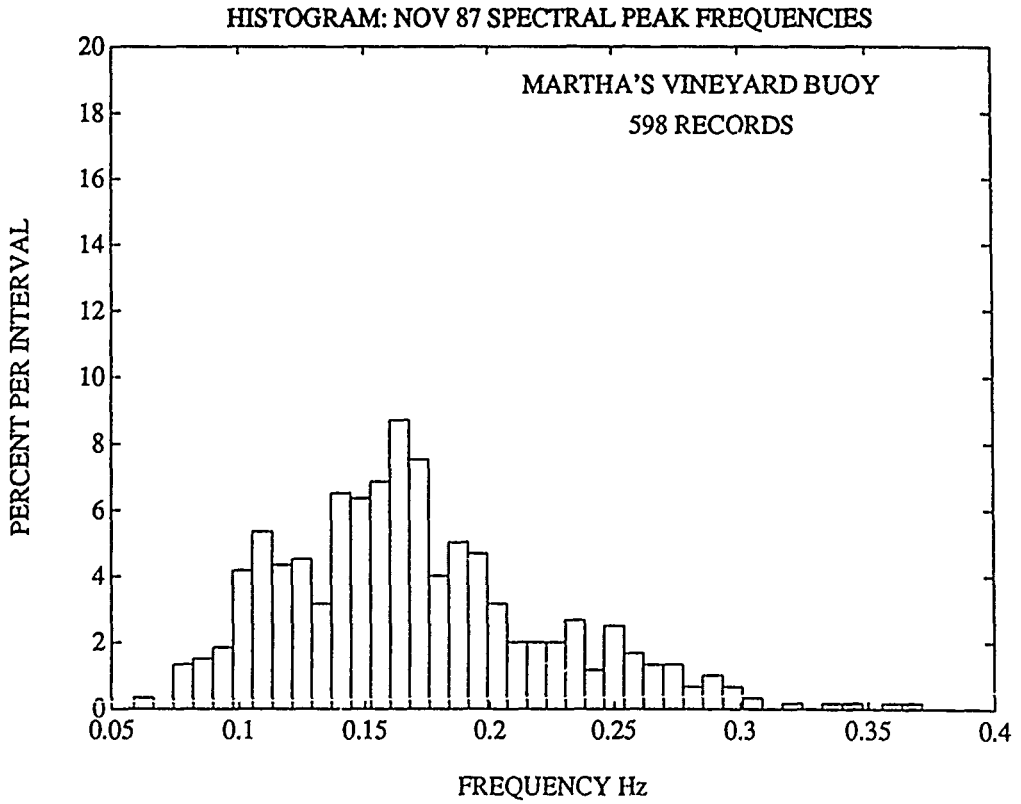


Figure 9: (continued) (e) Spectral peak period time series, and (f) spectral peak frequency distribution.

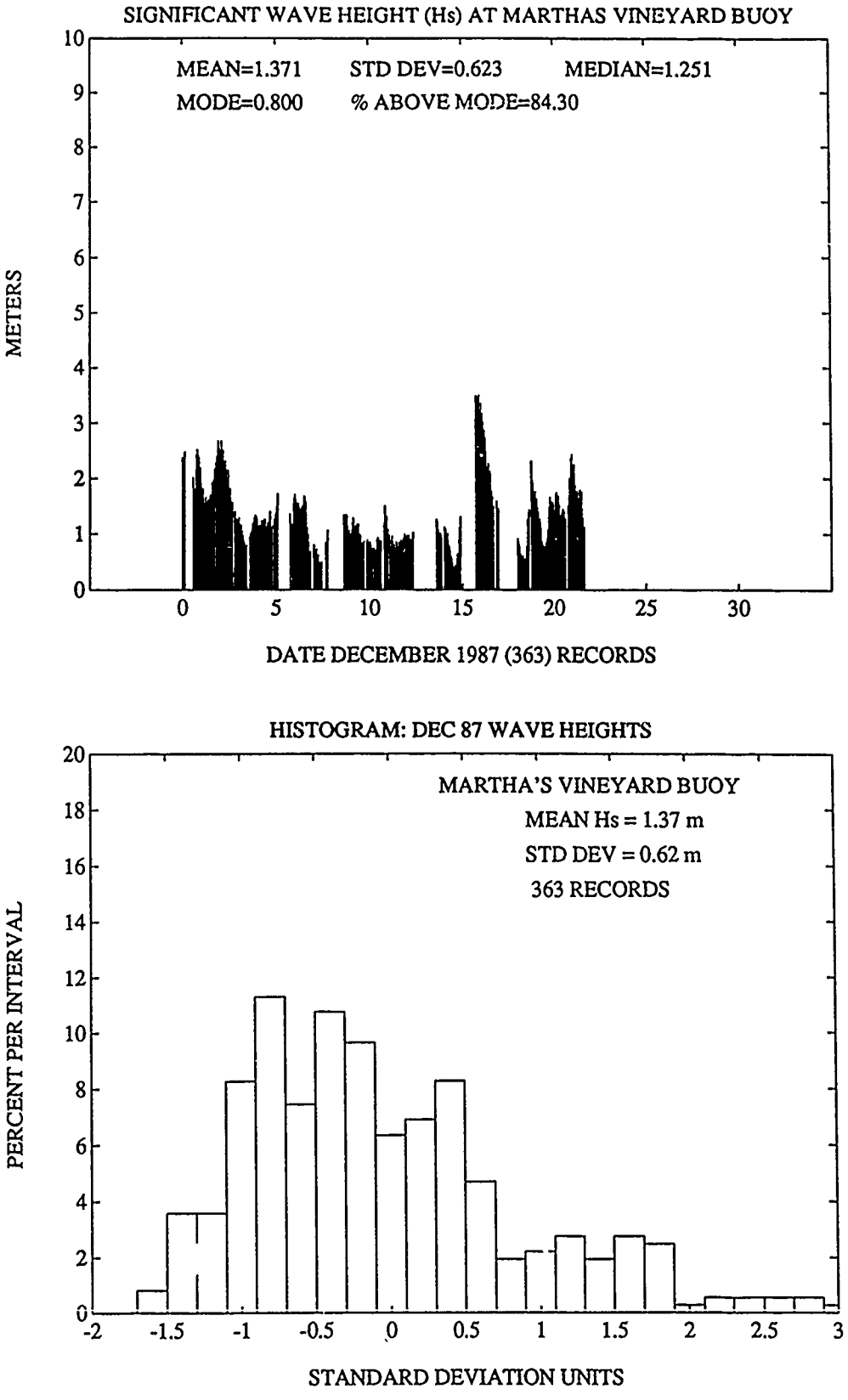
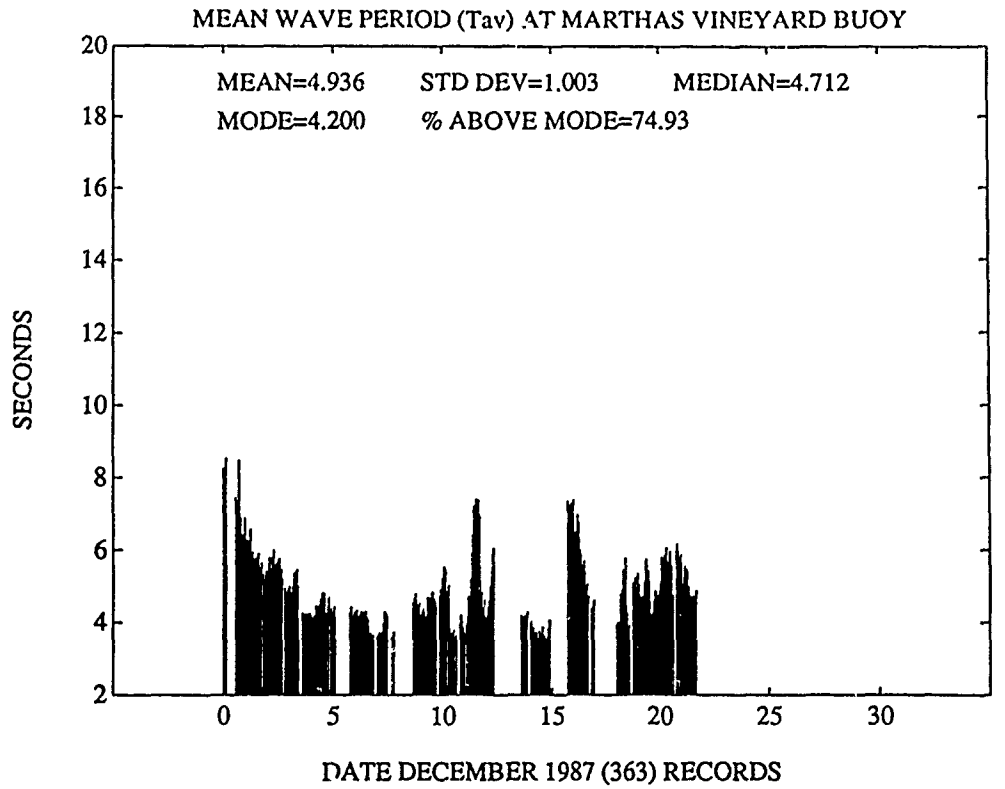


Figure 10: Wave height and period at Martha's Vineyard Buoy, December 1987. (a) Significant wave height time series, and (b) distribution.



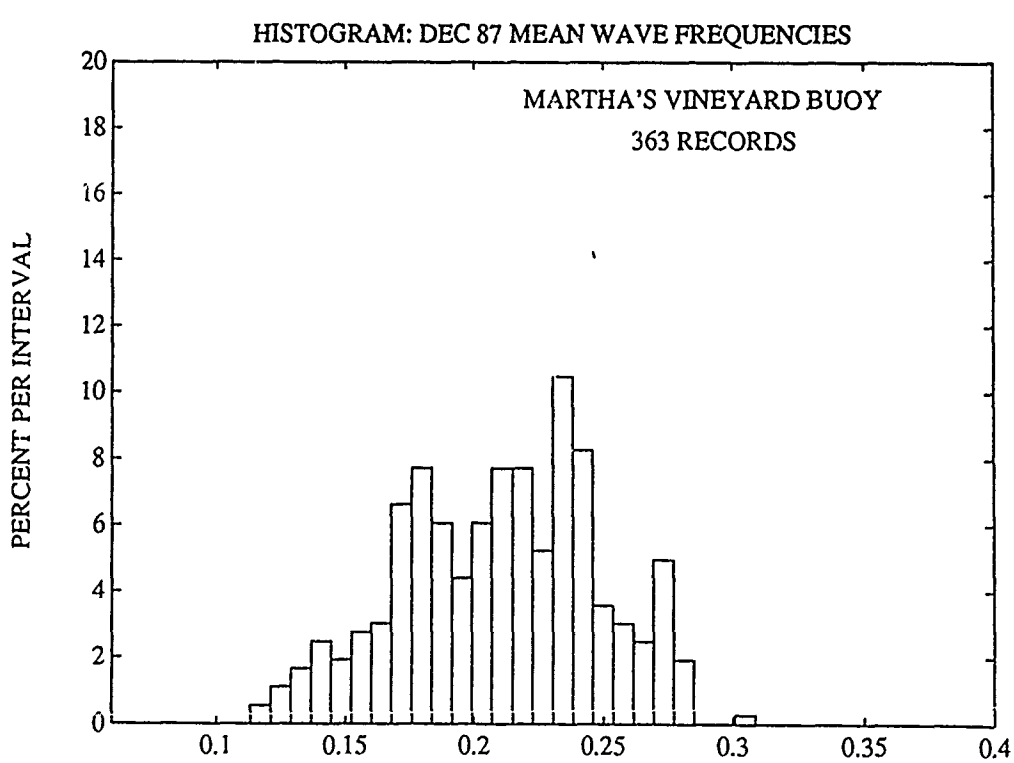
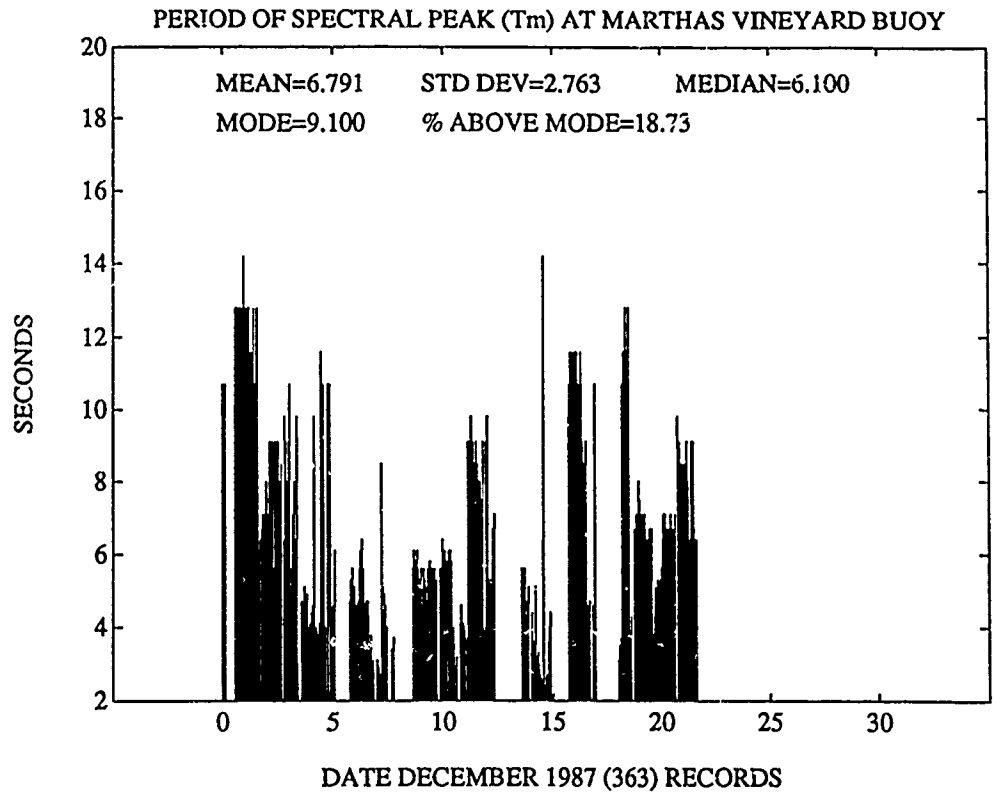


Figure 10: (continued) (c) Mean wave period time series, and (d) mean wave frequency distribution.



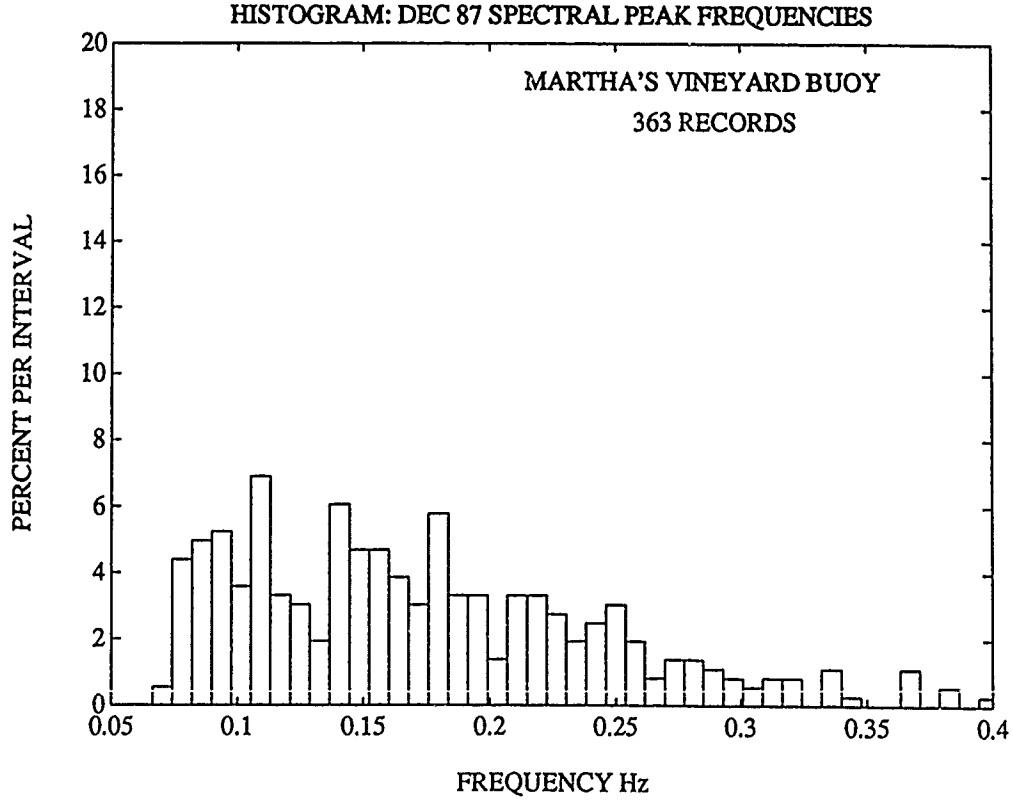


Figure 10: (continued) (e) Spectral peak period time series, and (f) spectral peak frequency distribution.

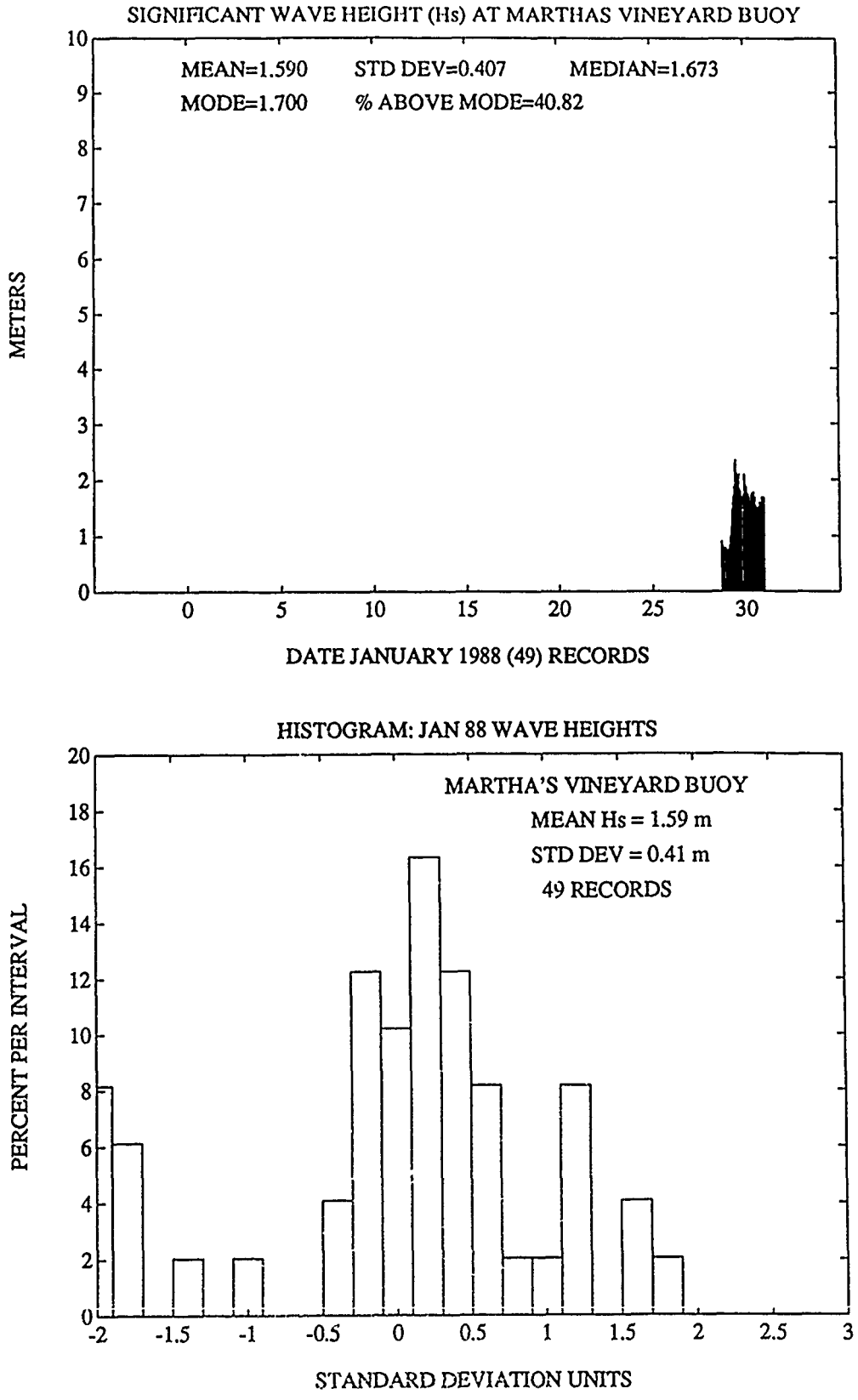
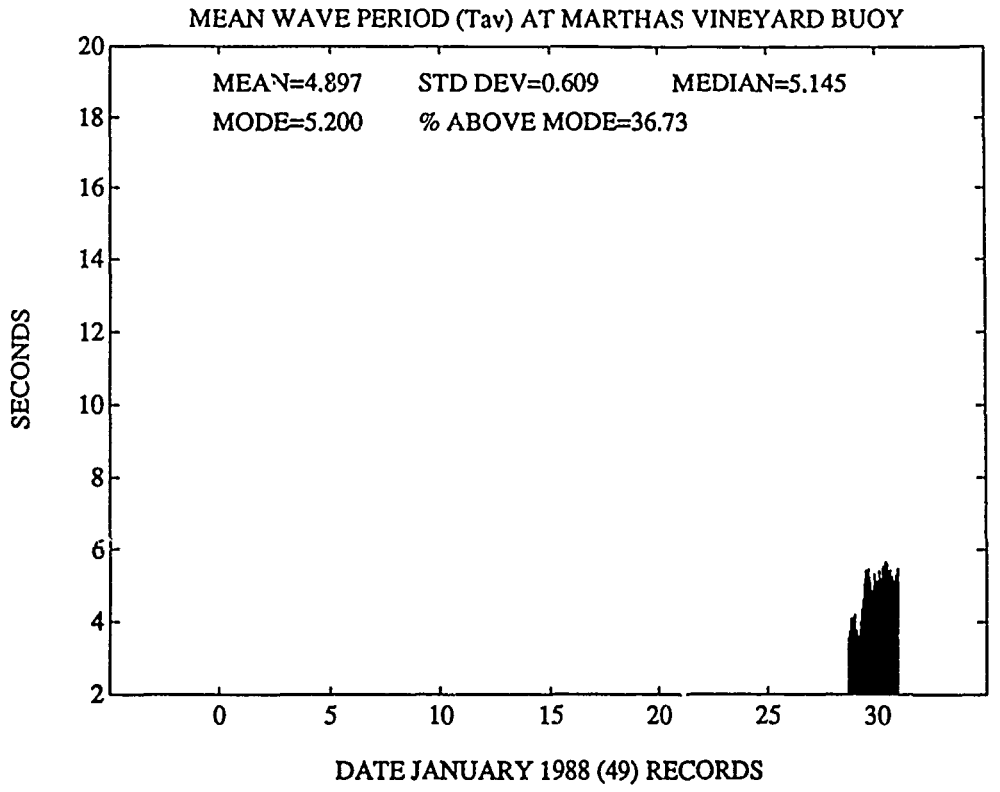


Figure 11: Wave height and period at Martha's Vineyard Buoy, January 1988. (a) Significant wave height time series, and (b) distribution.



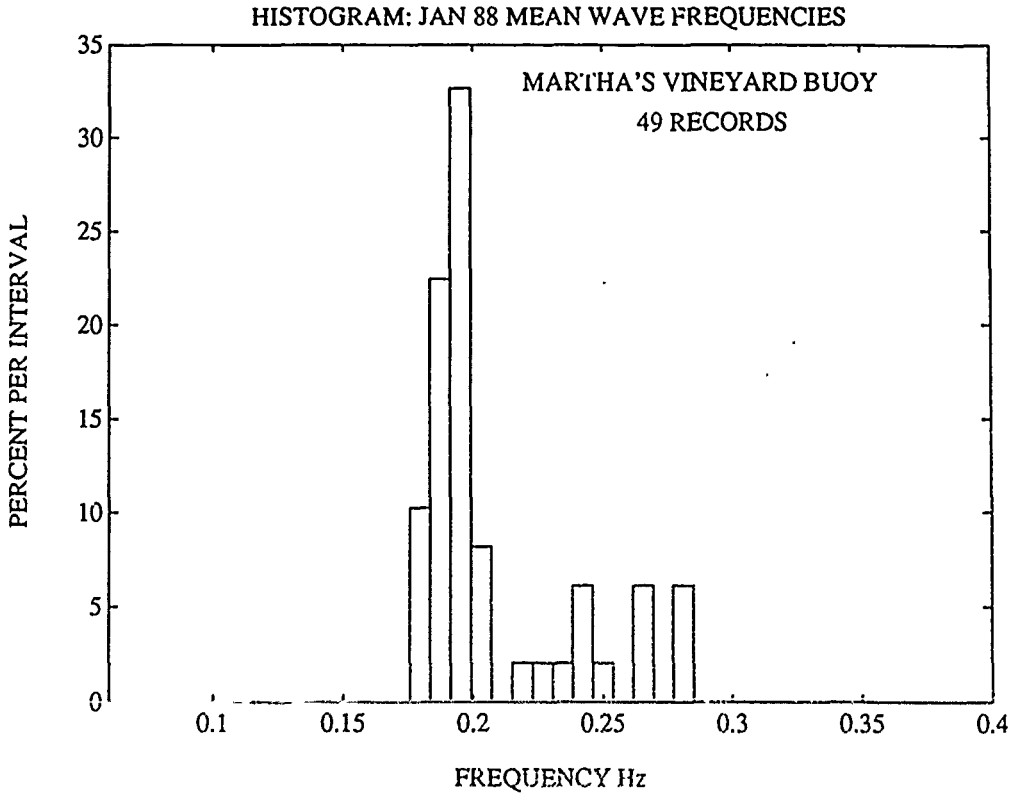
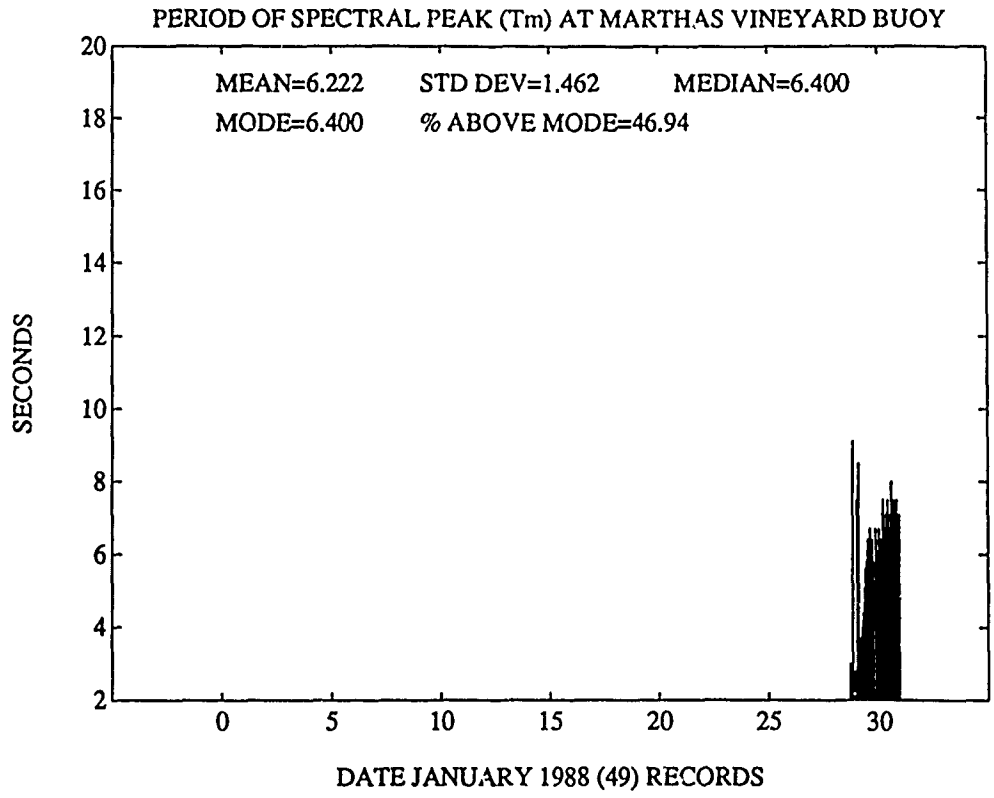


Figure 11: (continued) (c) Mean wave period time series, and (d) mean wave frequency distribution.



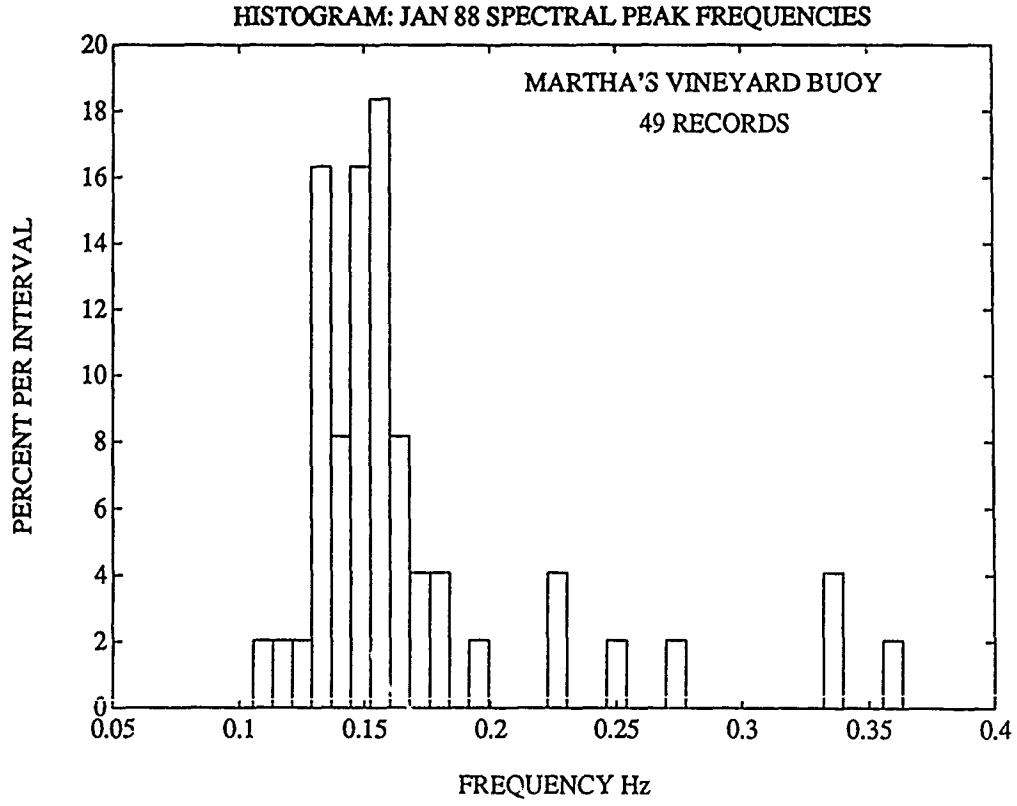
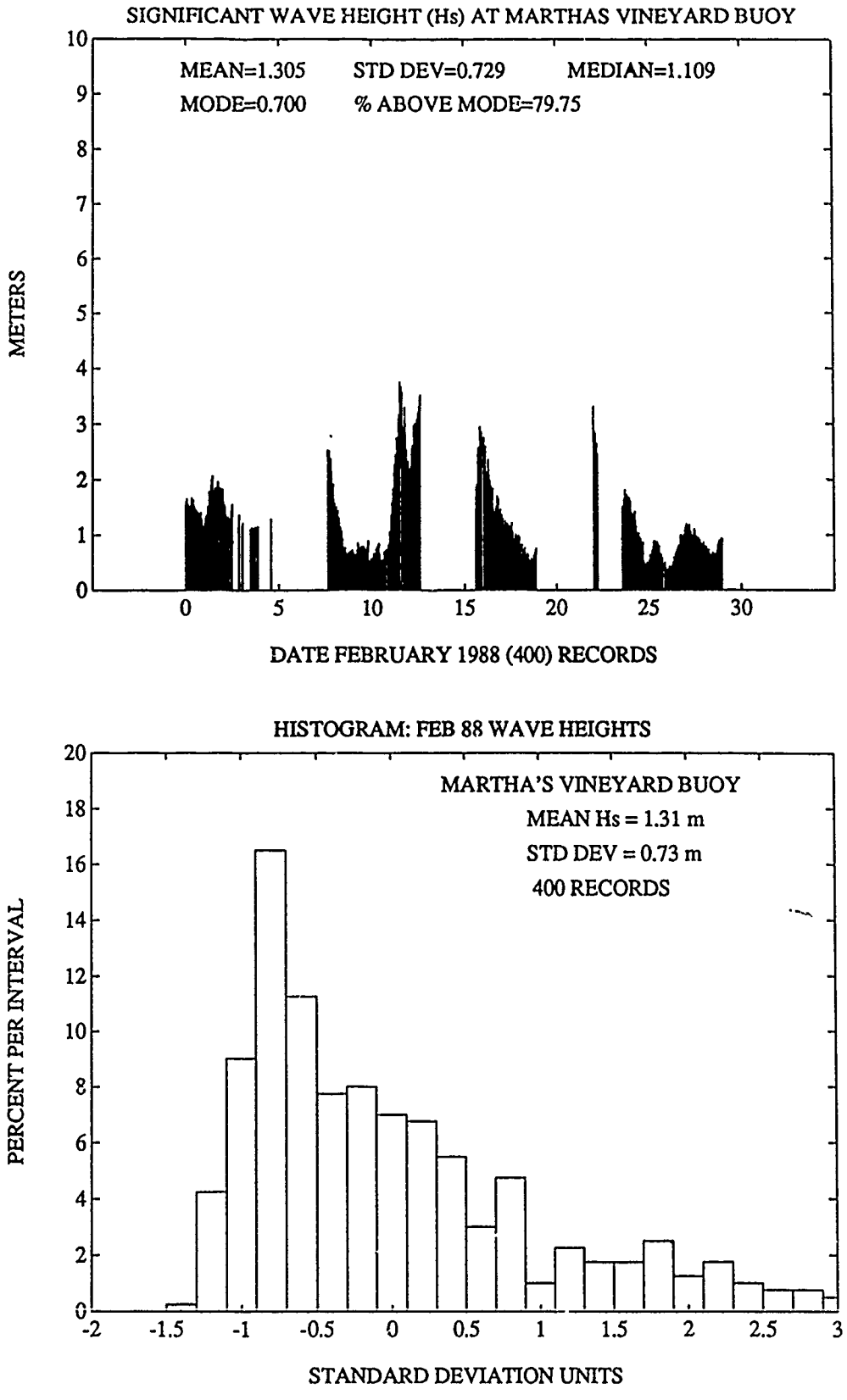


Figure 11: (continued) (e) Spectral peak period time series, and (f) spectral peak frequency distribution.



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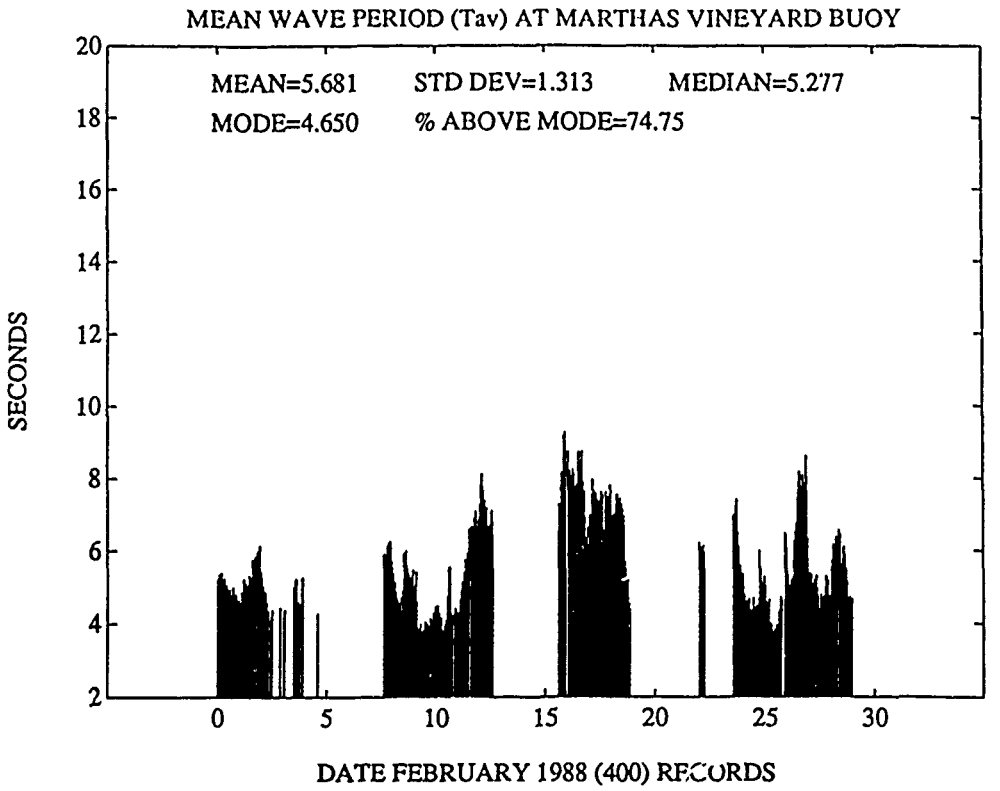


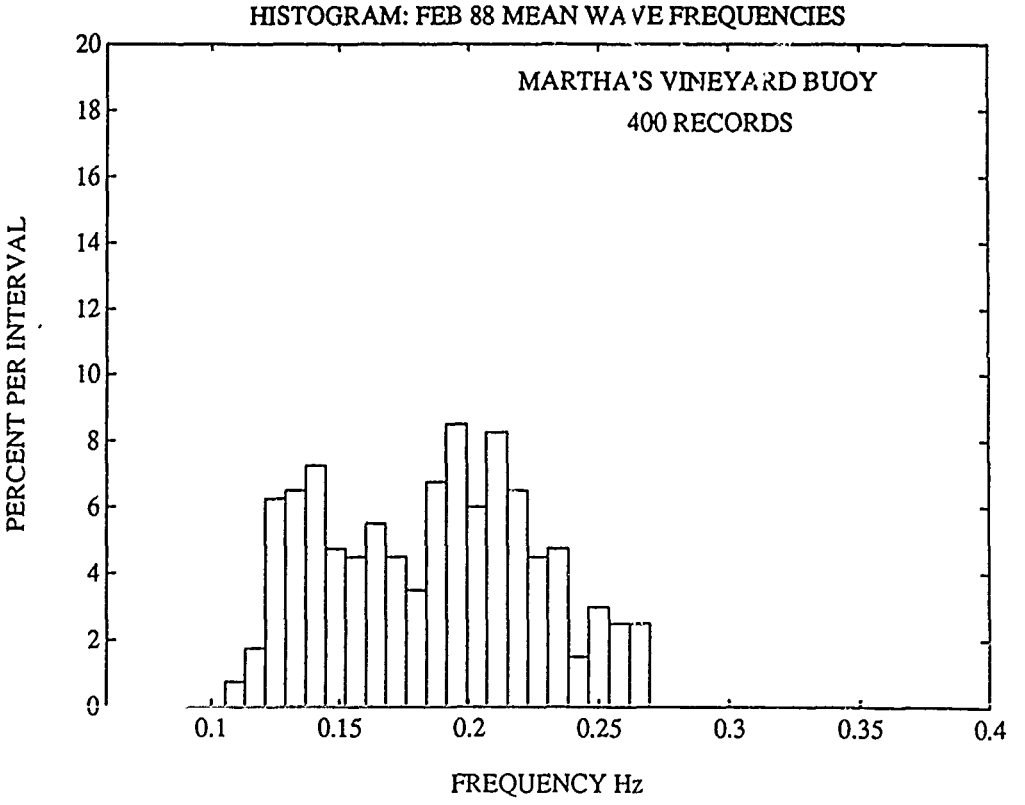
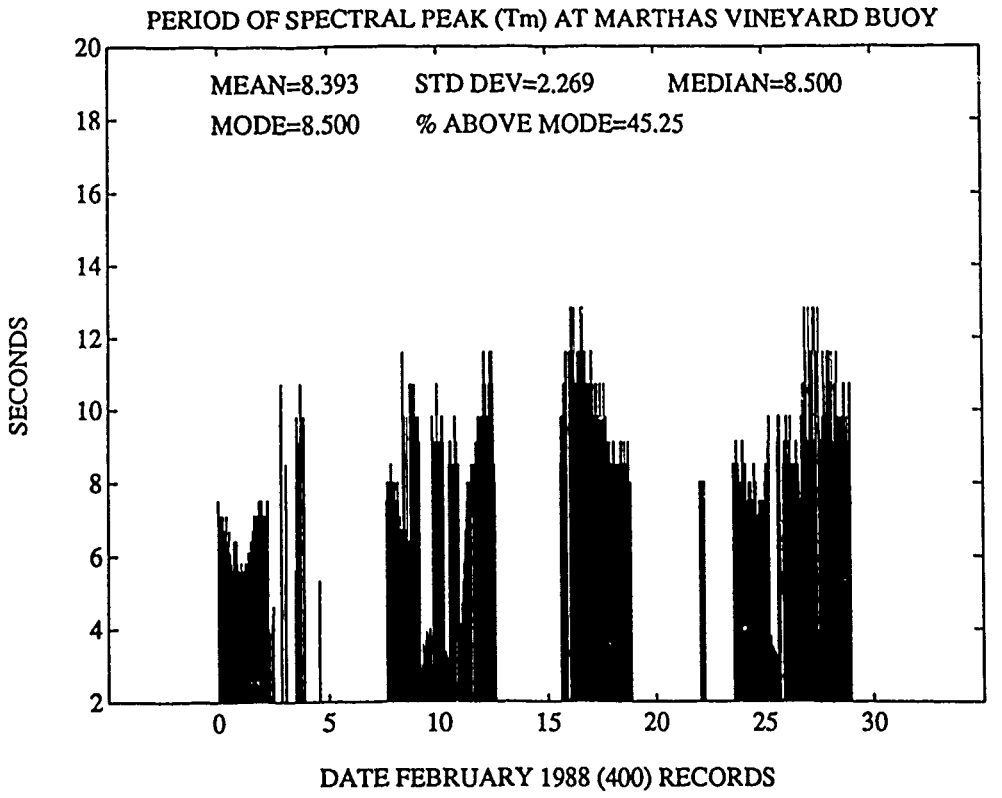


Figure 12: (continued) (c) Mean wave period time series, and (d) mean wave frequency distribution.



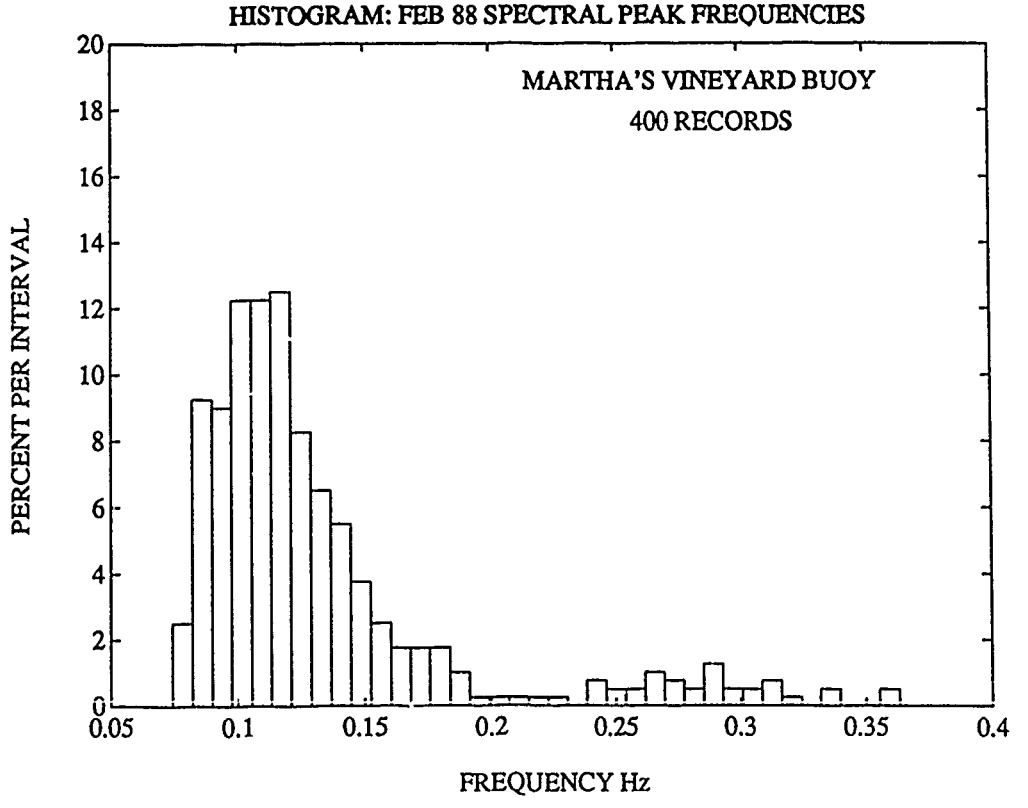


Figure 12: (continued) (e) Spectral peak period time series, and (f) spectral peak frequency distribution.

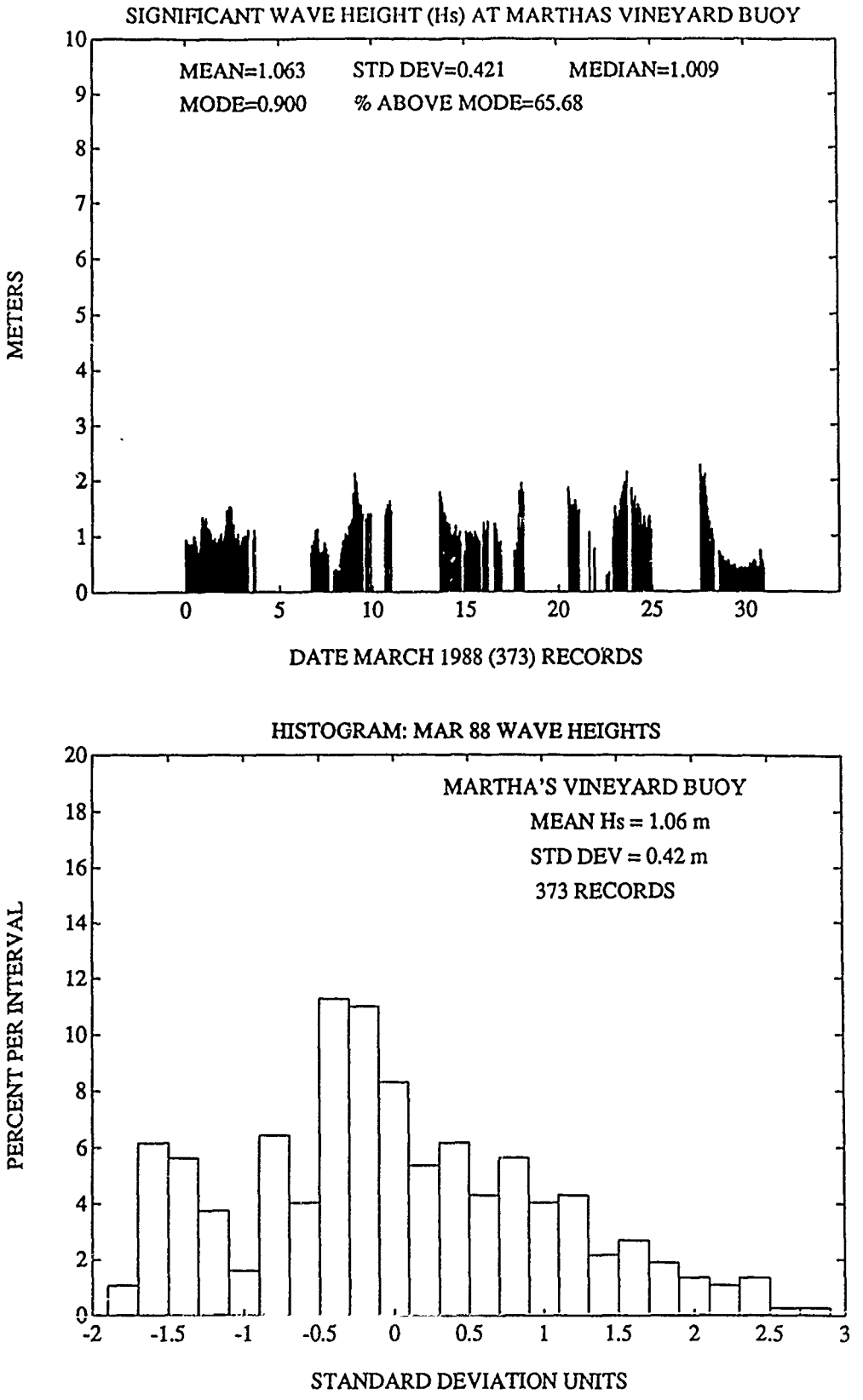


Figure 13: Wave height and period at Martha's Vineyard Buoy, March 1988. (a) Significant wave height time series, and (b) distribution.

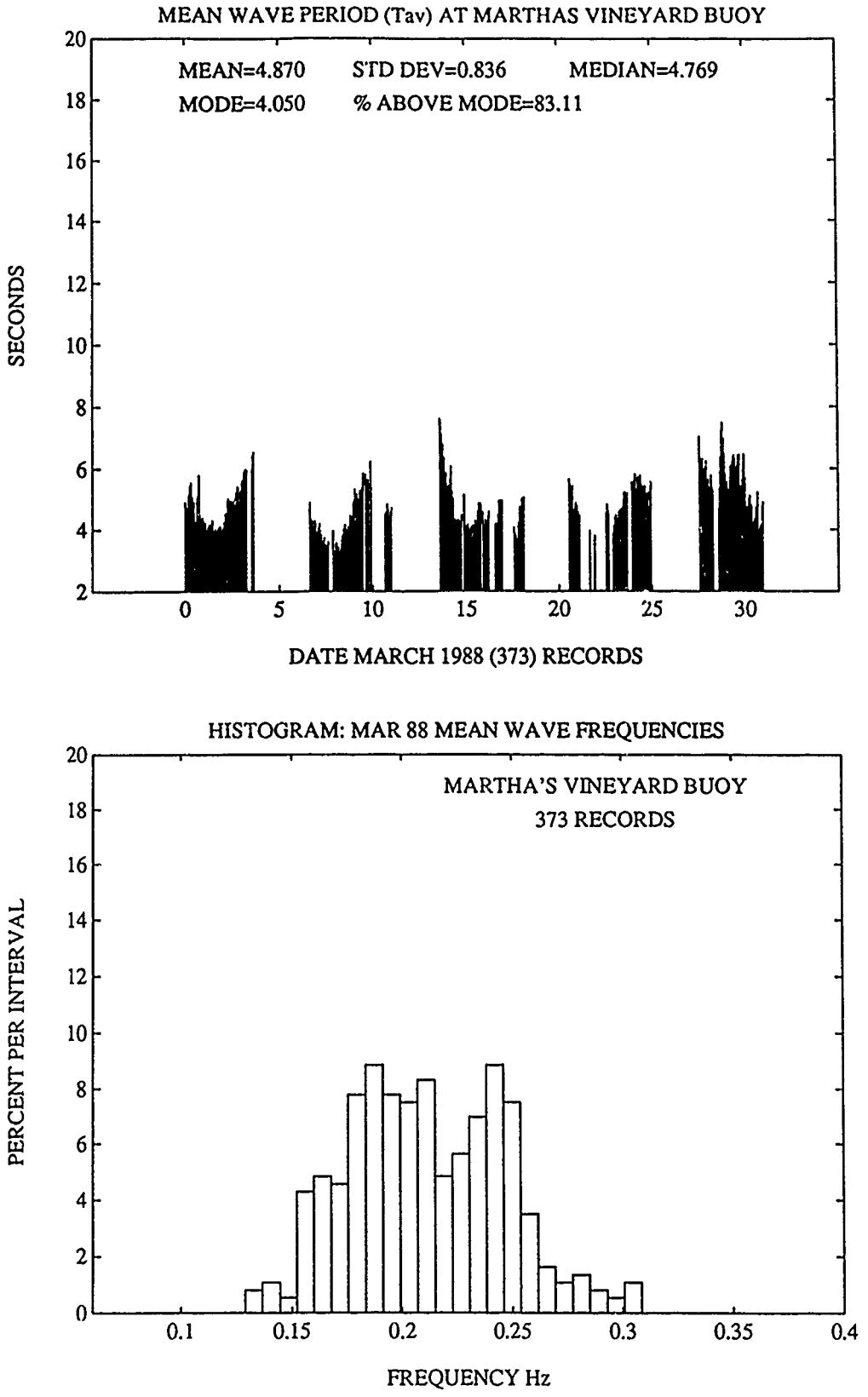
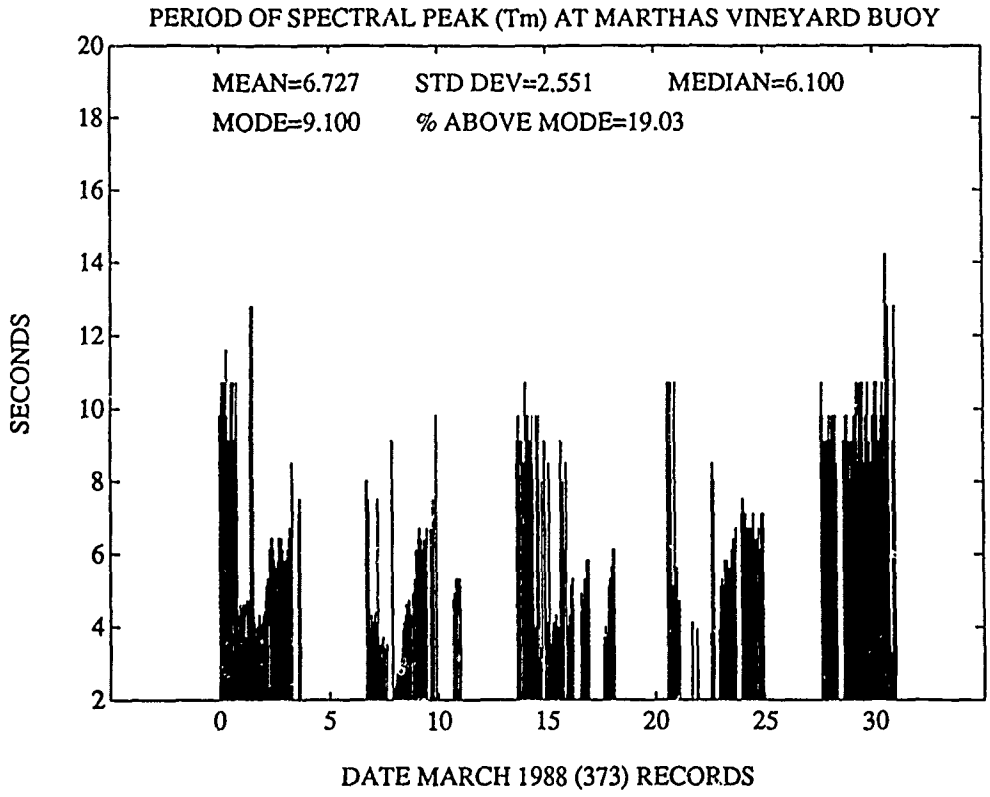


Figure 13: (continued) (c) Mean wave period time series, and (d) mean wave frequency distribution.



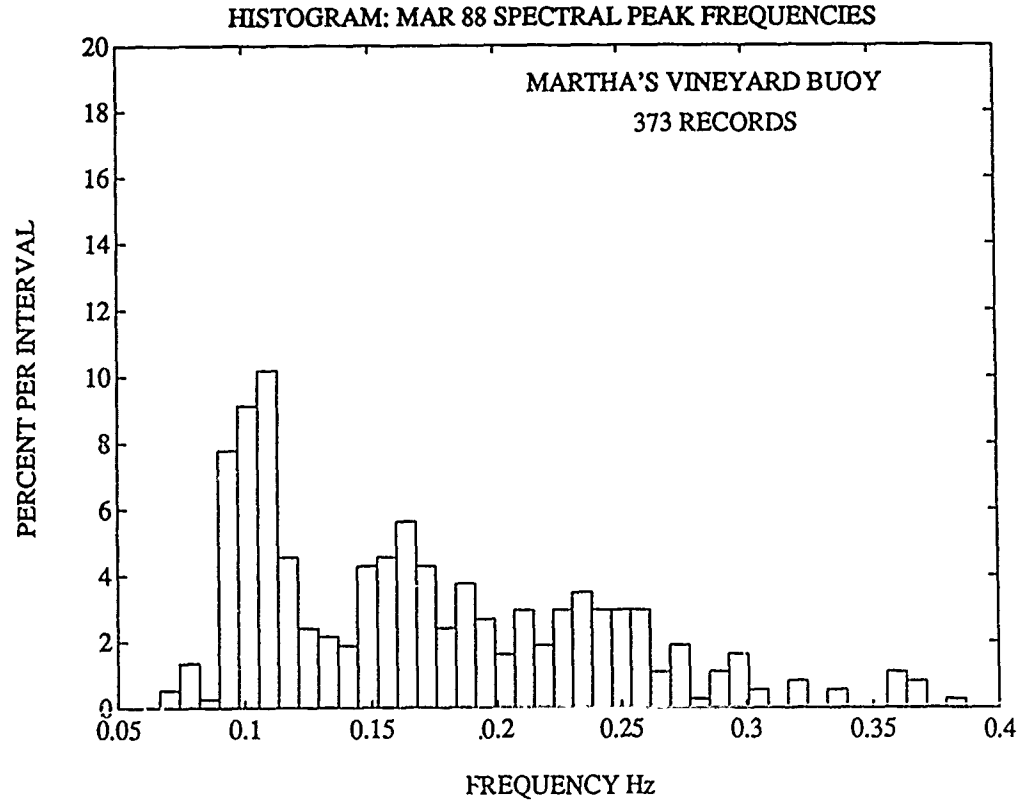


Figure 13: (continued) (e) Spectral peak period time series, and (f) spectral peak frequency distribution.

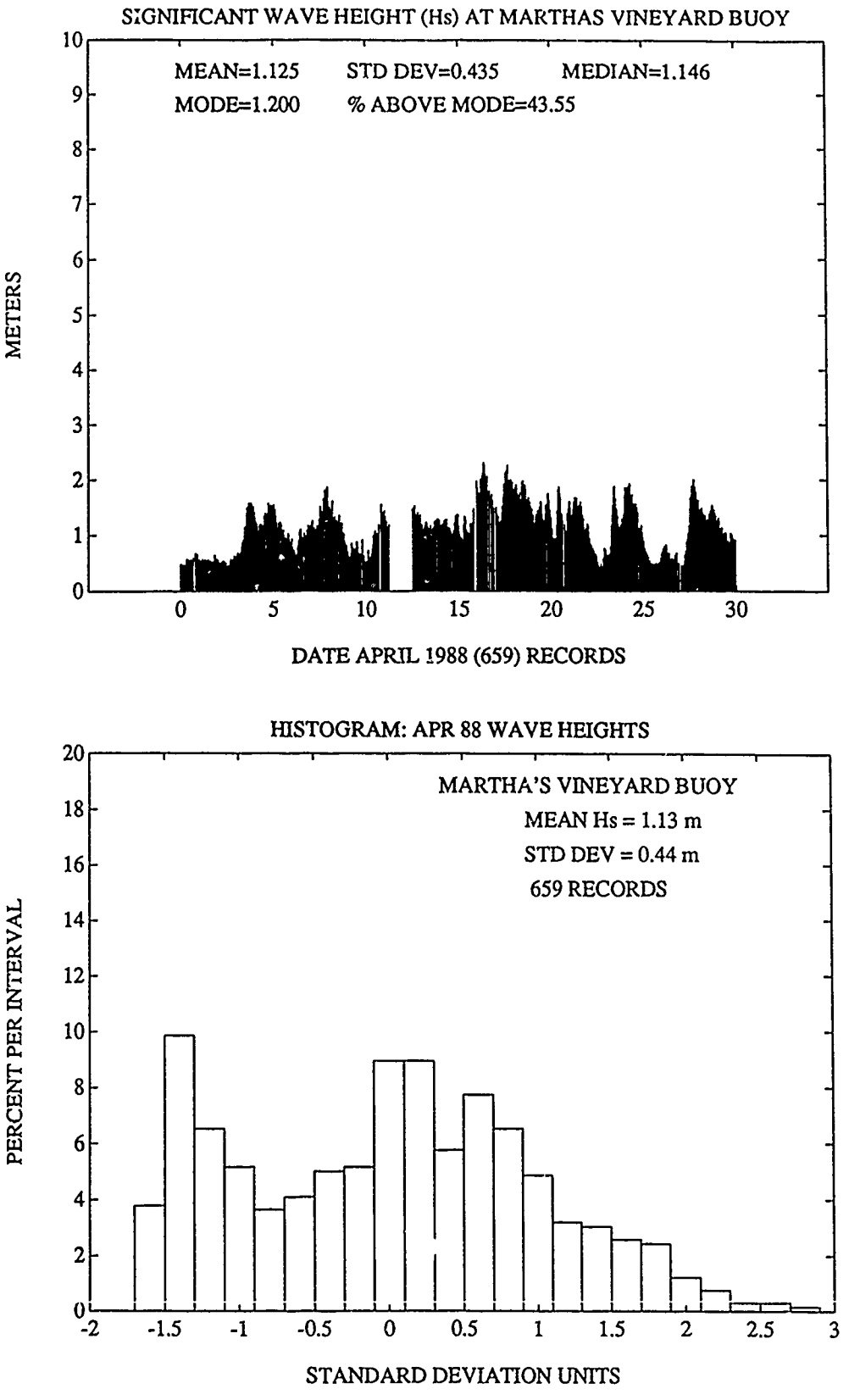


Figure 14: Wave height and period at Martha's Vineyard Buoy, April 1988. (a) Significant wave height time series, and (b) distribution.

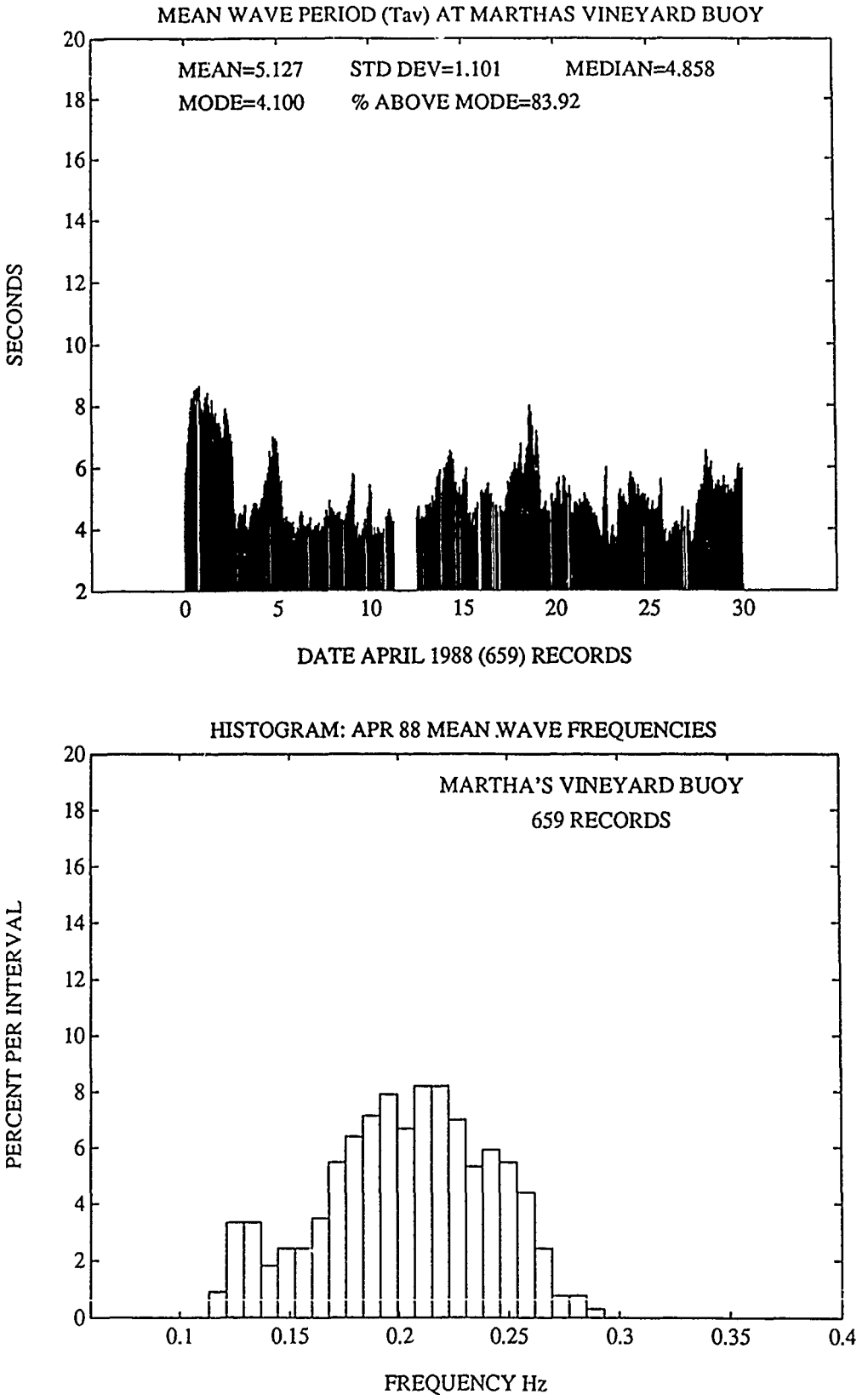
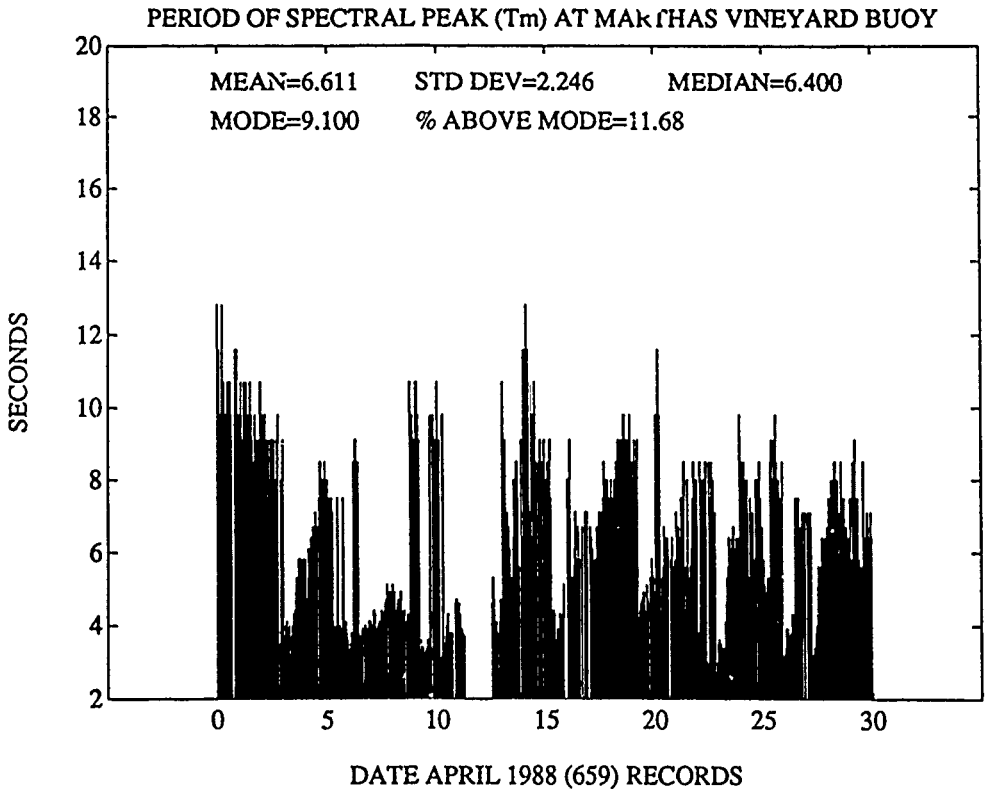


Figure 14: (continued) (c) Mean wave period time series, and (d) mean wave frequency distribution.



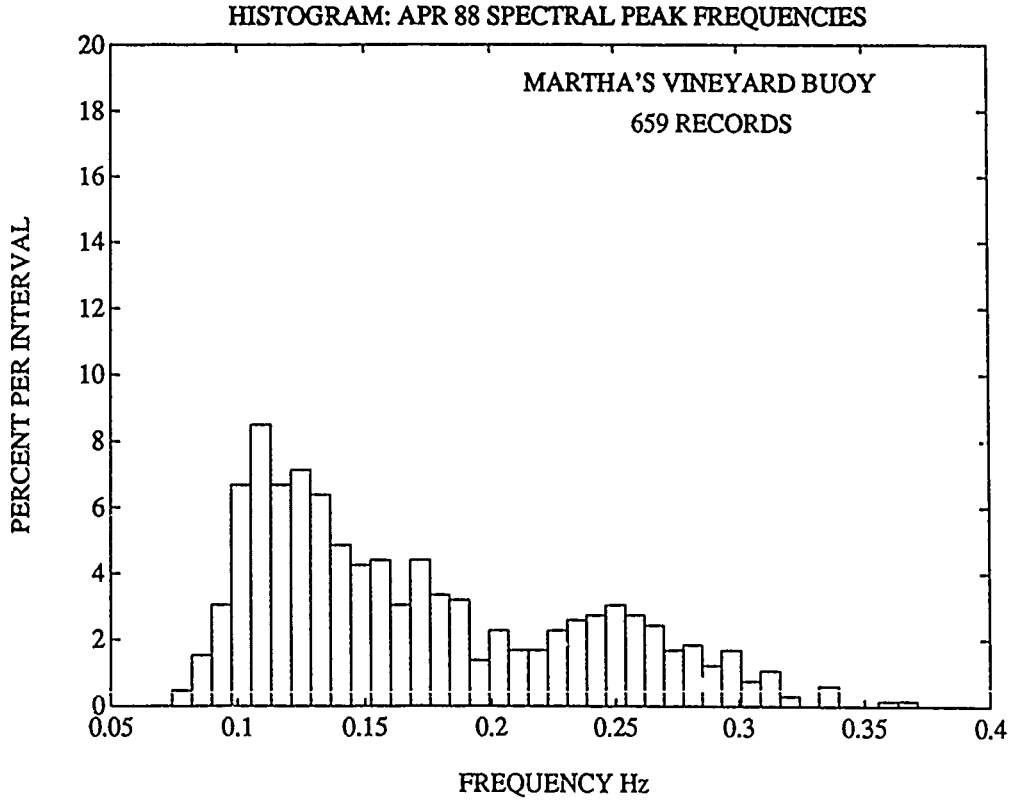


Figure 14: (continued) (e) Spectral peak period time series, and (f) spectral peak frequency distribution.

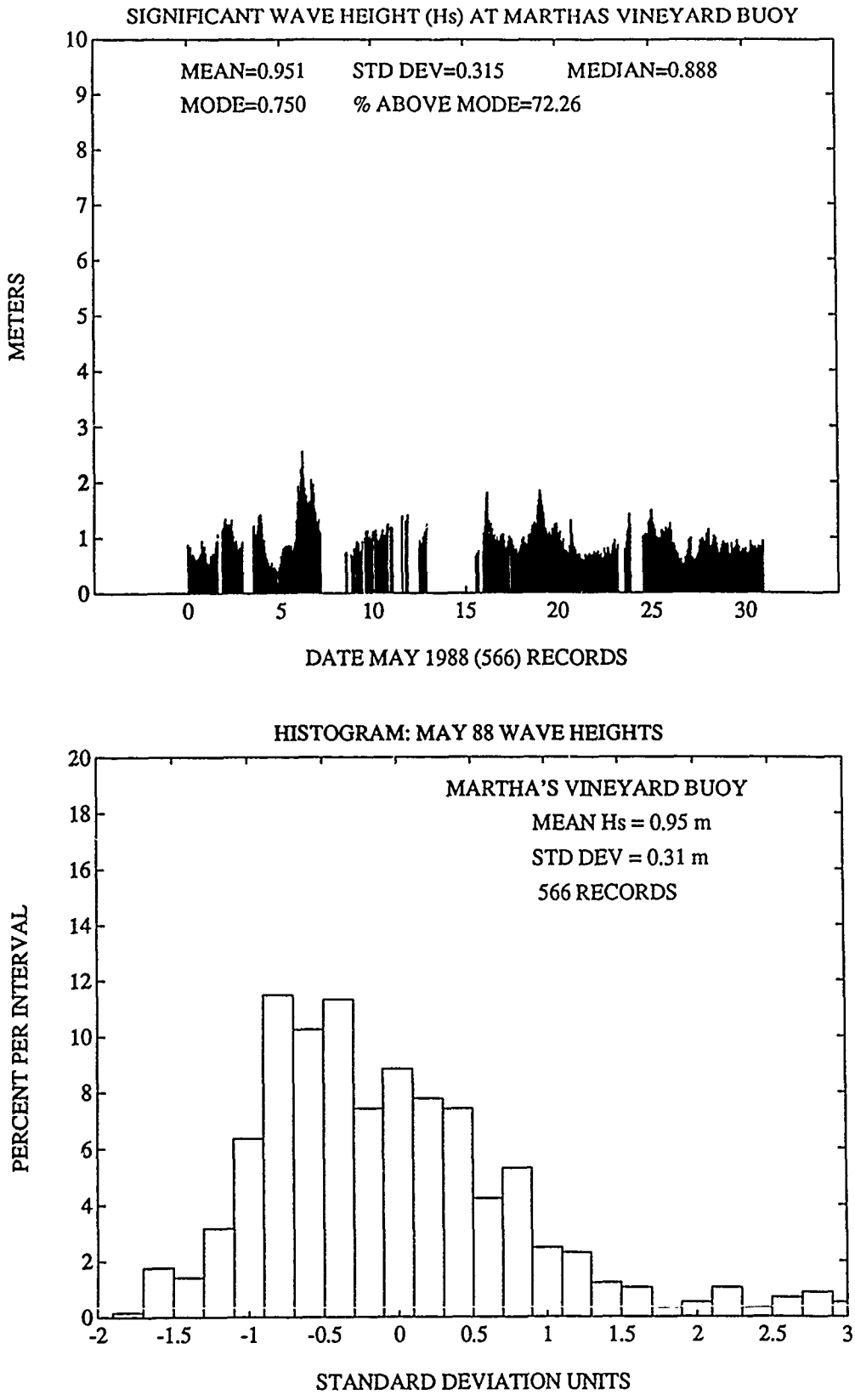
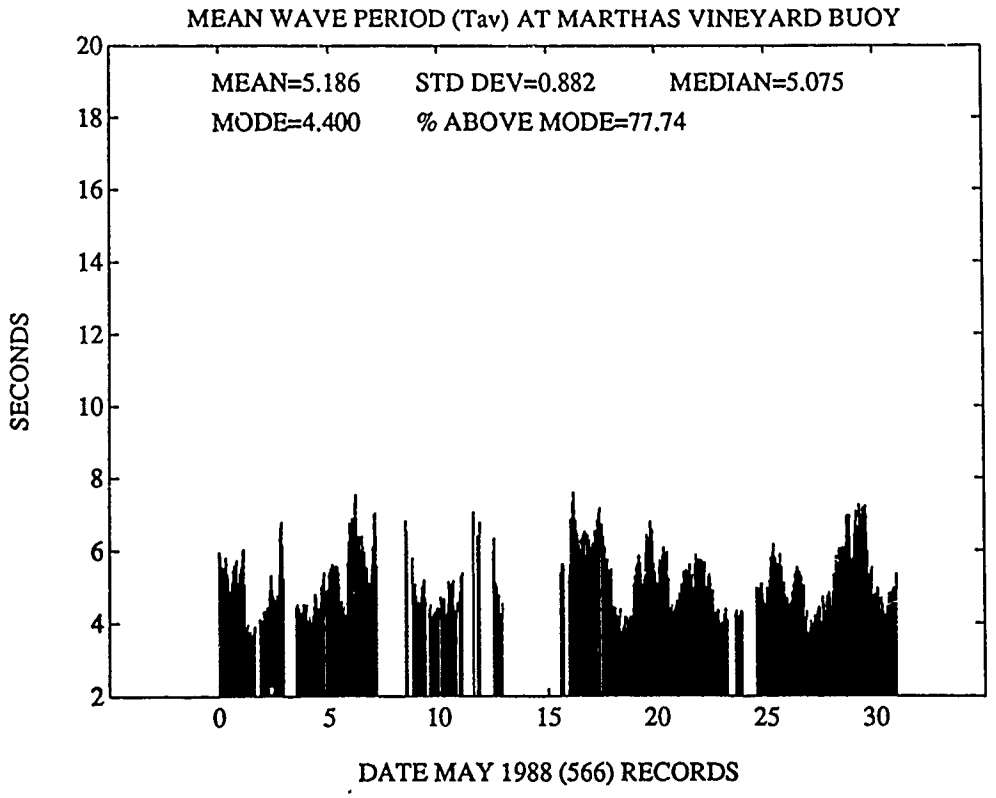


Figure 15: Wave height and period at Martha's Vineyard Buoy, May 1988. (a) Significant wave height time series, and (b) distribution.



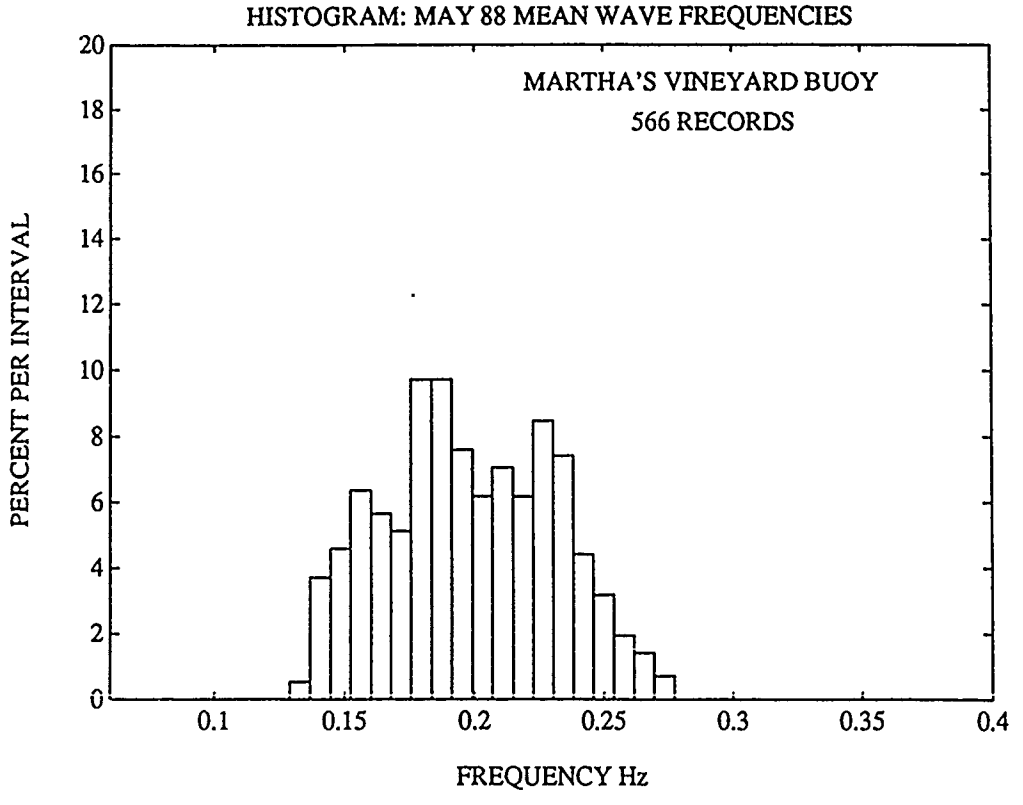
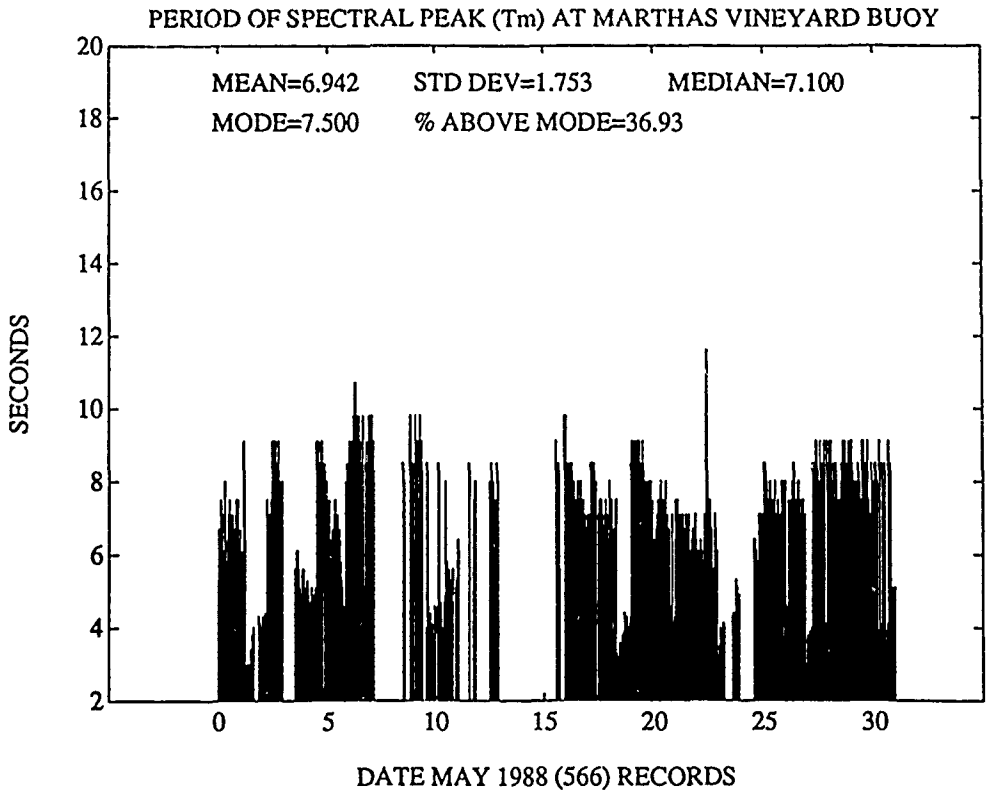


Figure 15: (continued) (c) Mean wave period time series, and (d) mean wave frequency distribution.



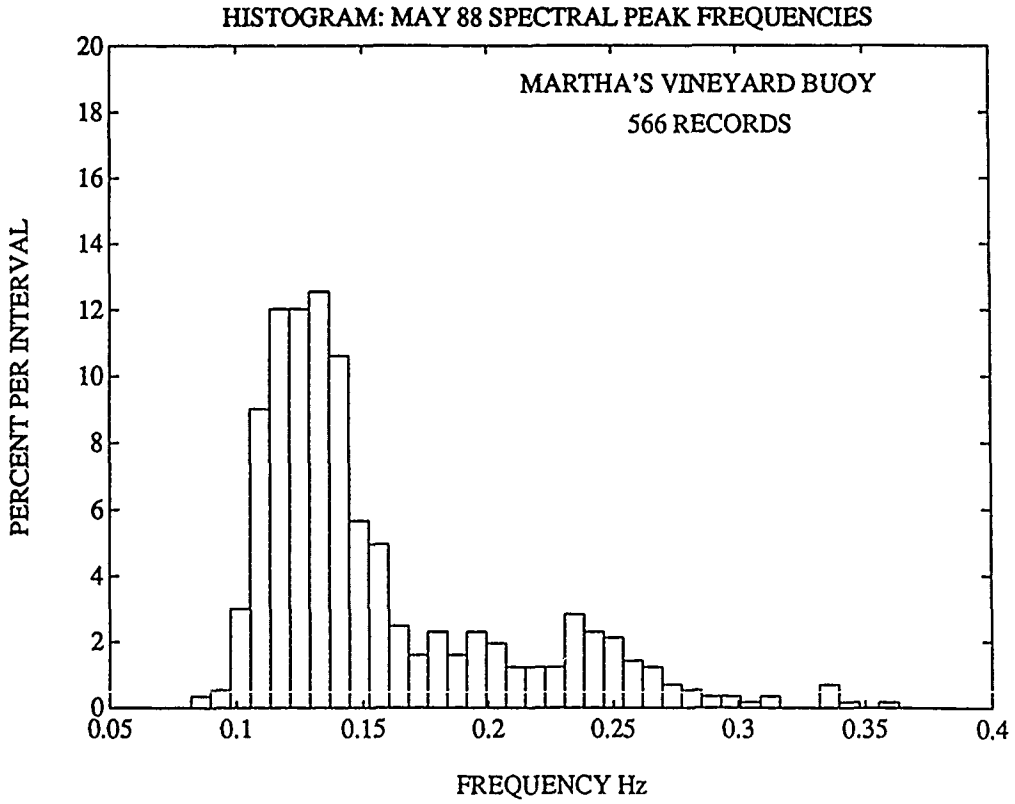


Figure 15: (continued) (e) Spectral peak period time series, and (f) spectral peak frequency distribution.

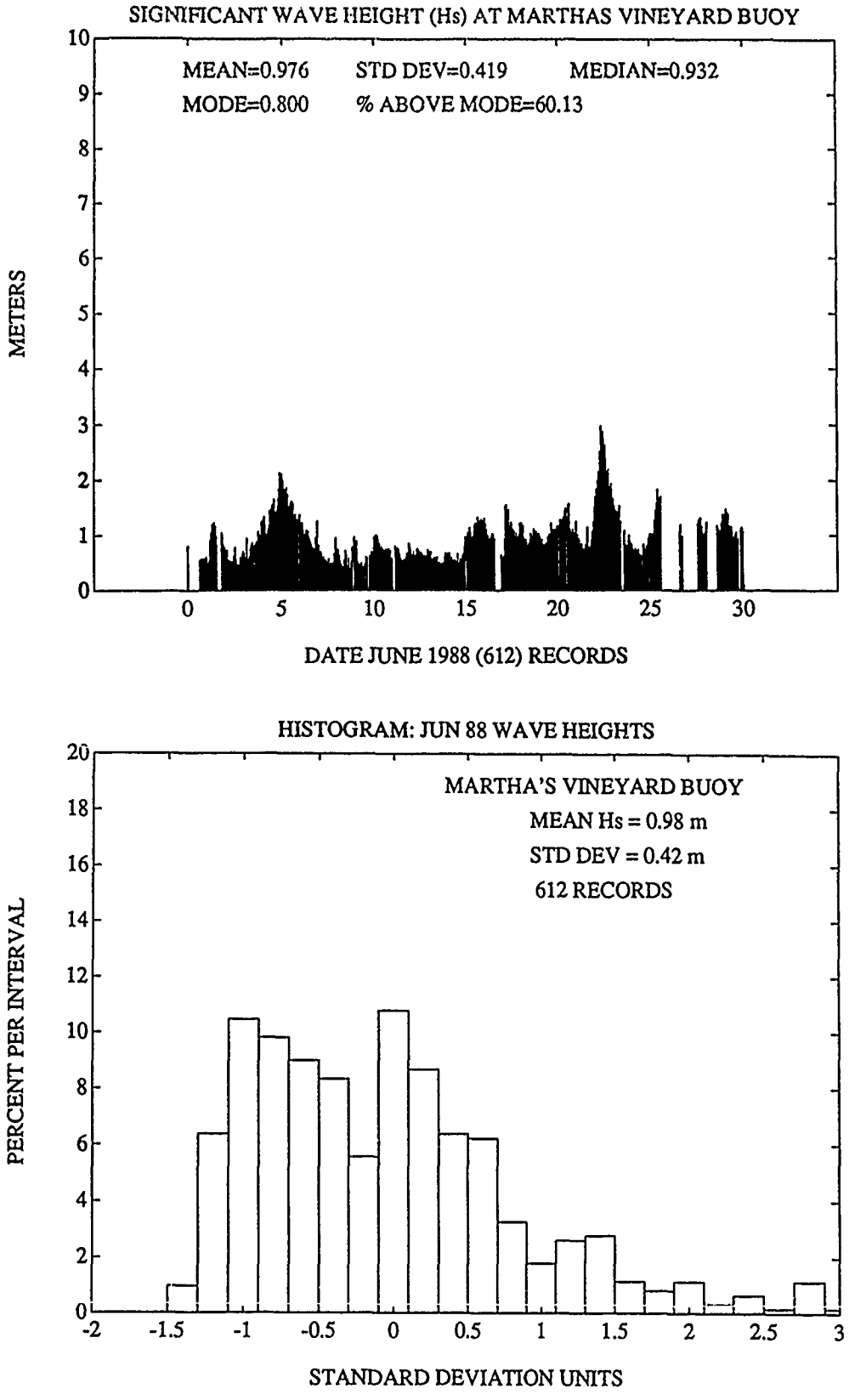
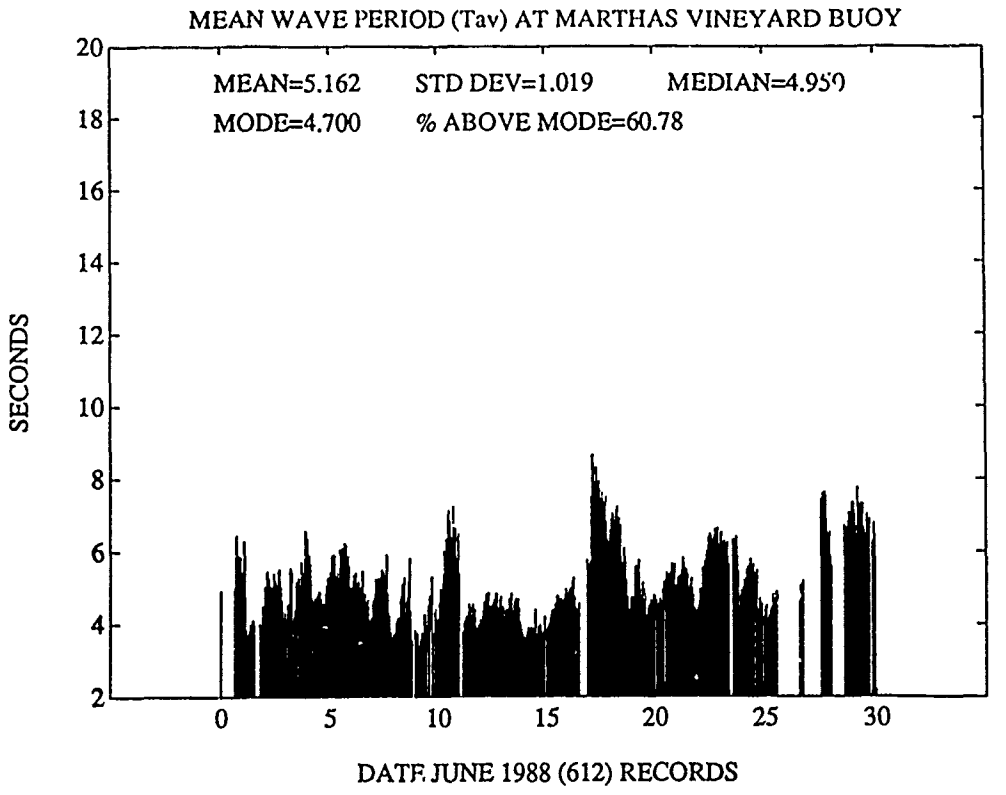


Figure 16: Wave height and period at Martha's Vineyard Buoy, June 1988. (a) Significant wave height time series, and (b) distribution.



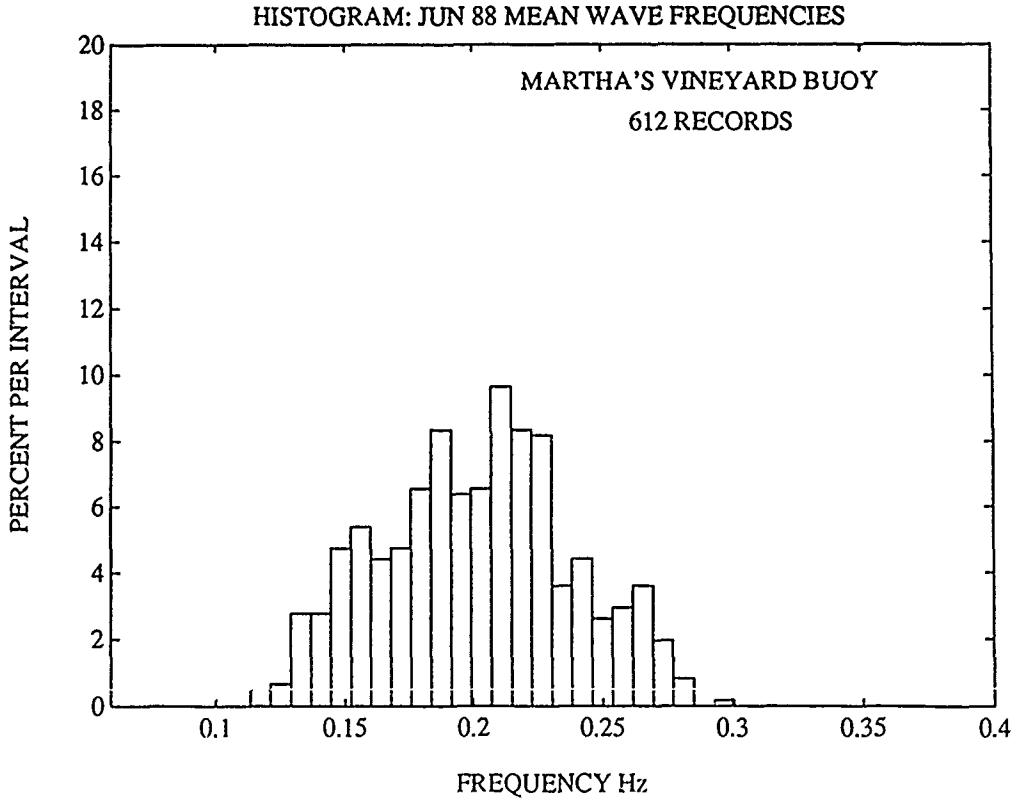
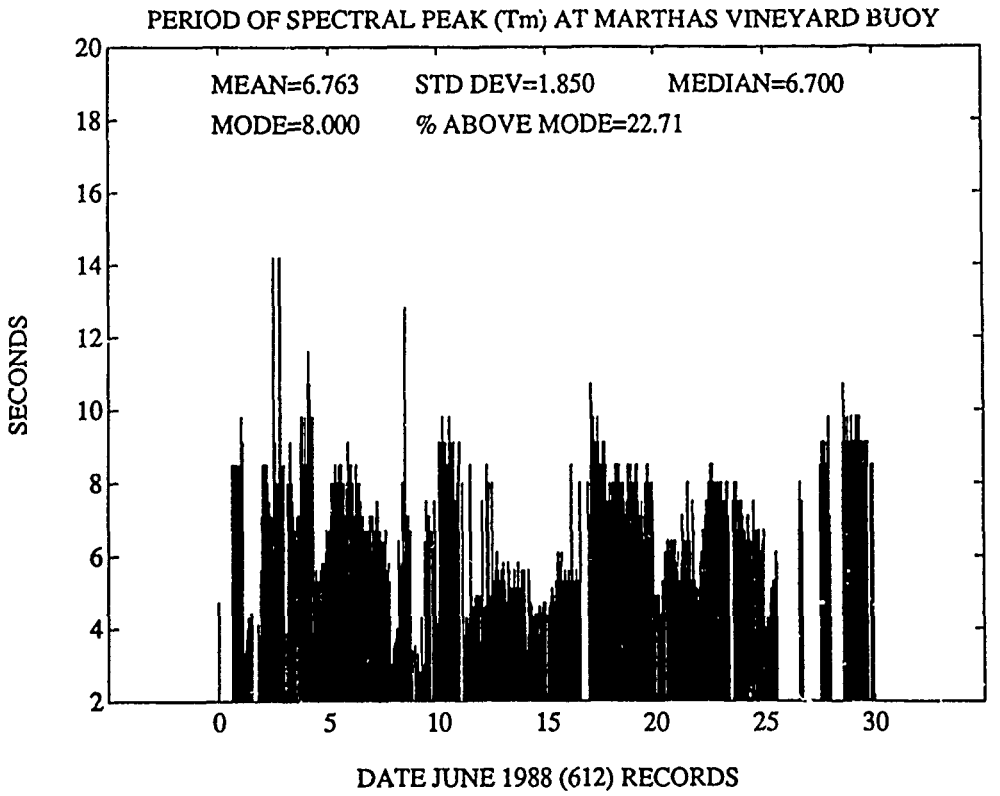


Figure 16: (continued) (c) Mean wave period time series, and (d) mean wave frequency distribution.



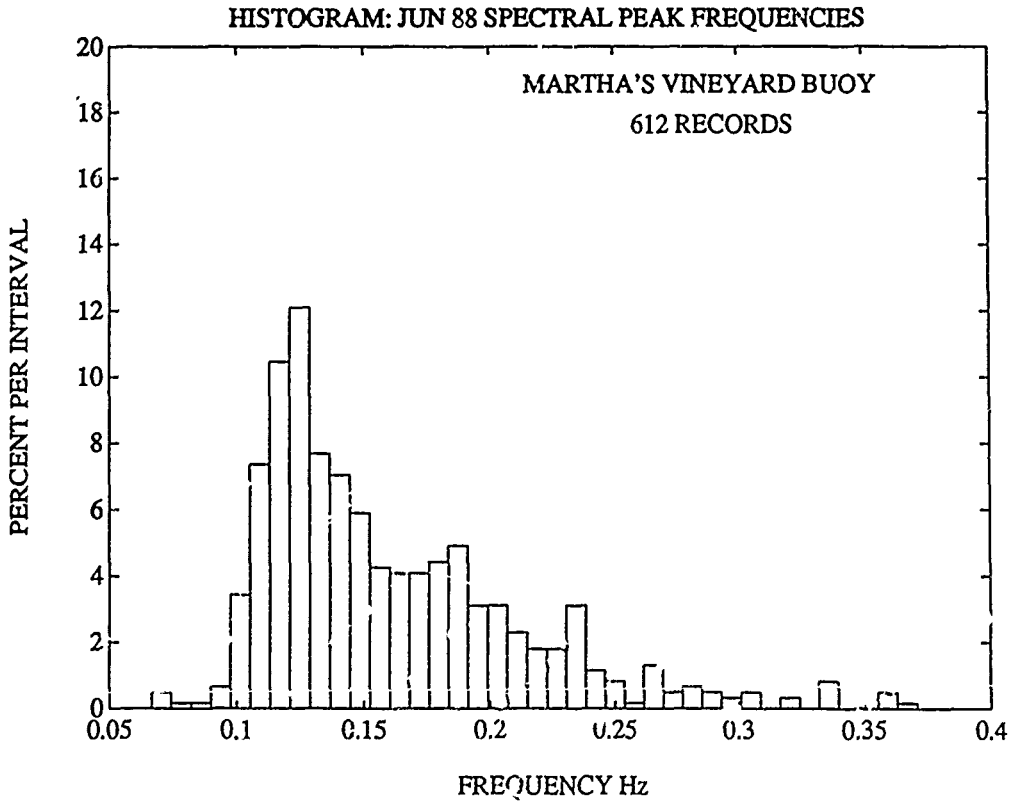


Figure 16: (continued) (e) Spectral peak period time series, and (f) spectral peak frequency distribution.

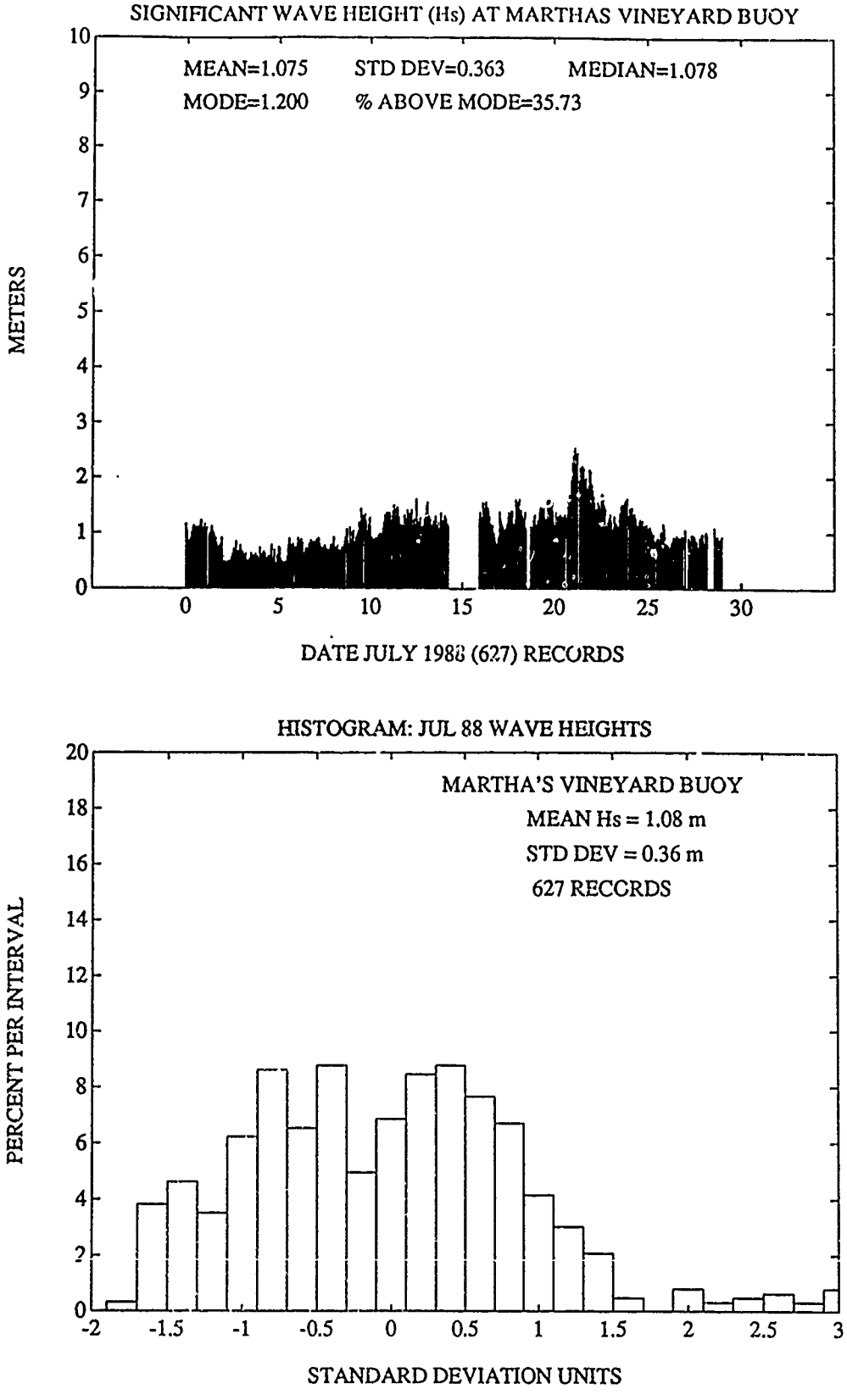


Figure 17: Wave height and period at Martha's Vineyard Buoy, July 1988. (a) Significant wave height time series, and (b) distribution.

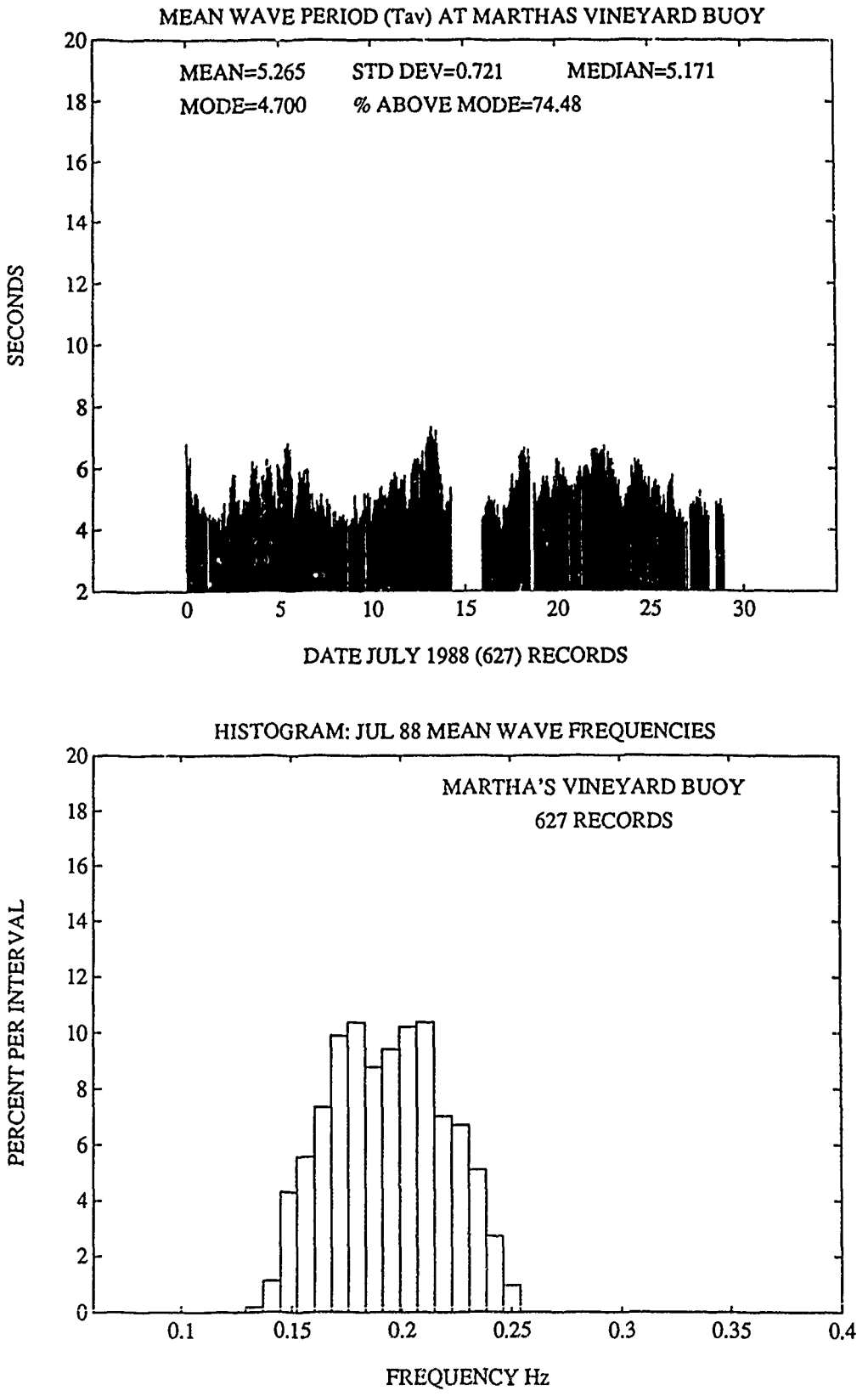
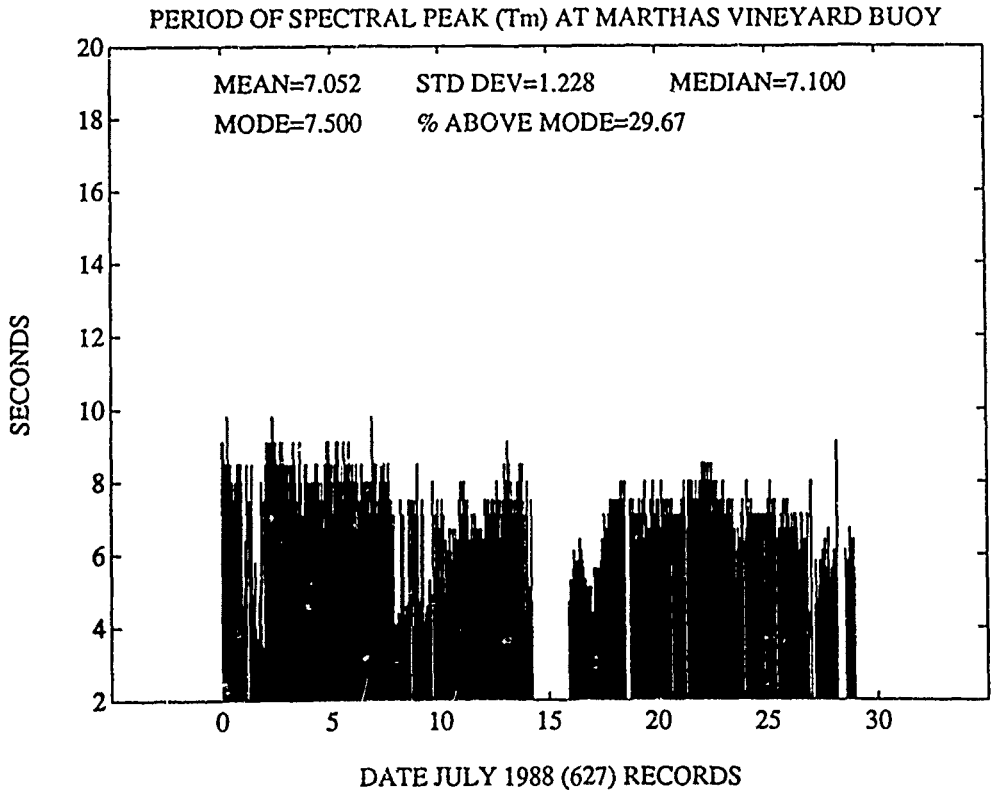


Figure 17: (continued) (c) Mean wave period time series, and (d) mean wave frequency distribution.



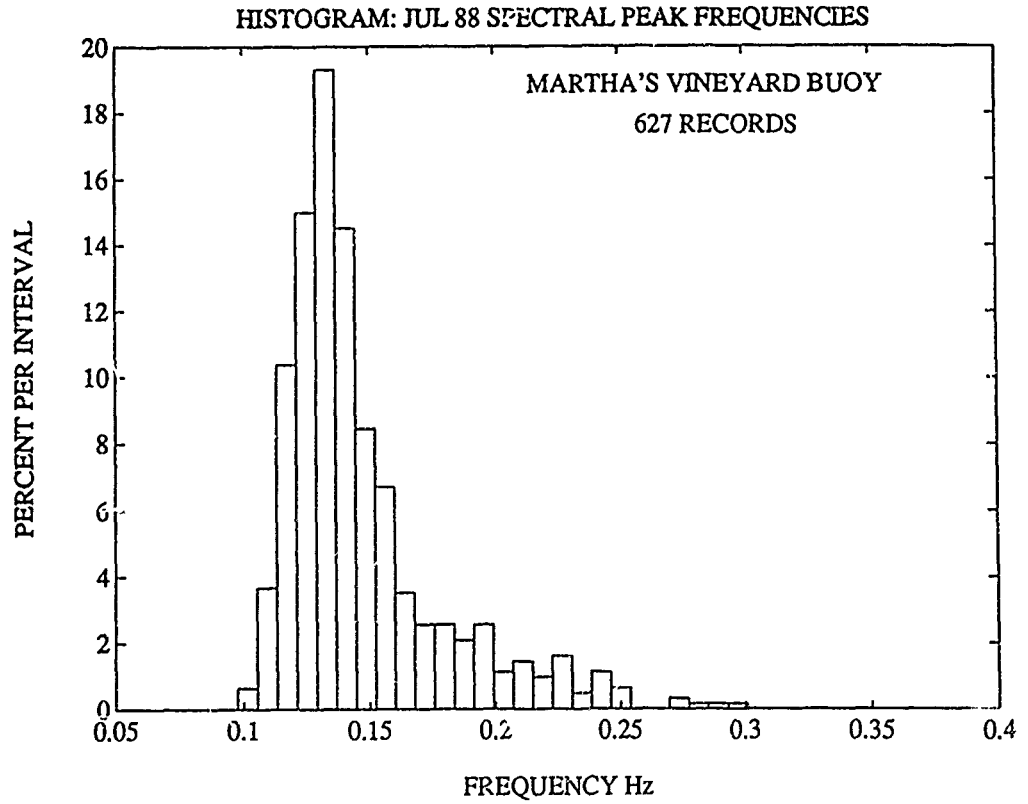


Figure 17: (continued) (e) Spectral peak period time series, and (f) spectral peak frequency distribution.

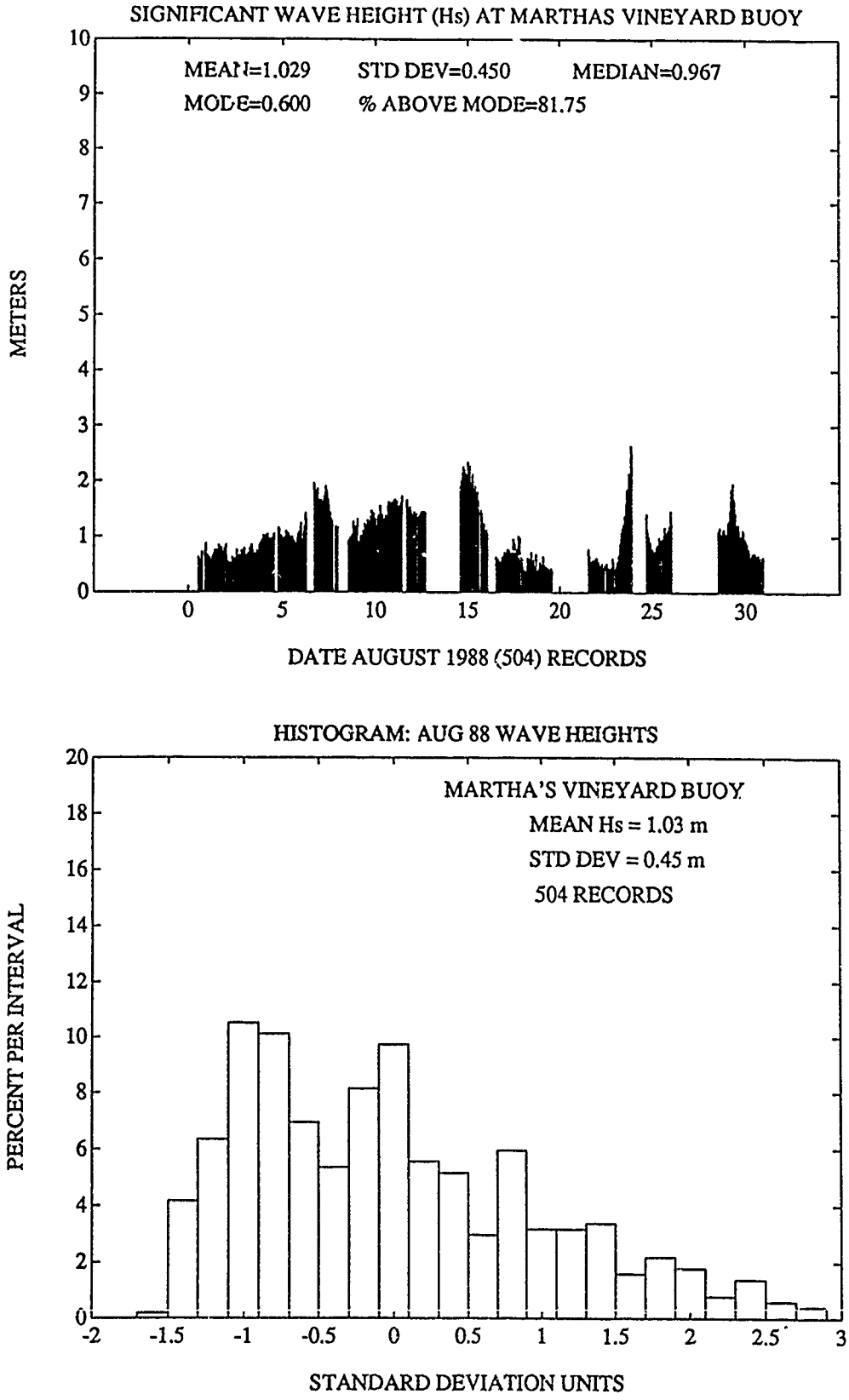


Figure 18: Wave height and period at Martha's Vineyard Buoy, August 1988. (a) Significant wave height time series, and (b) distribution.

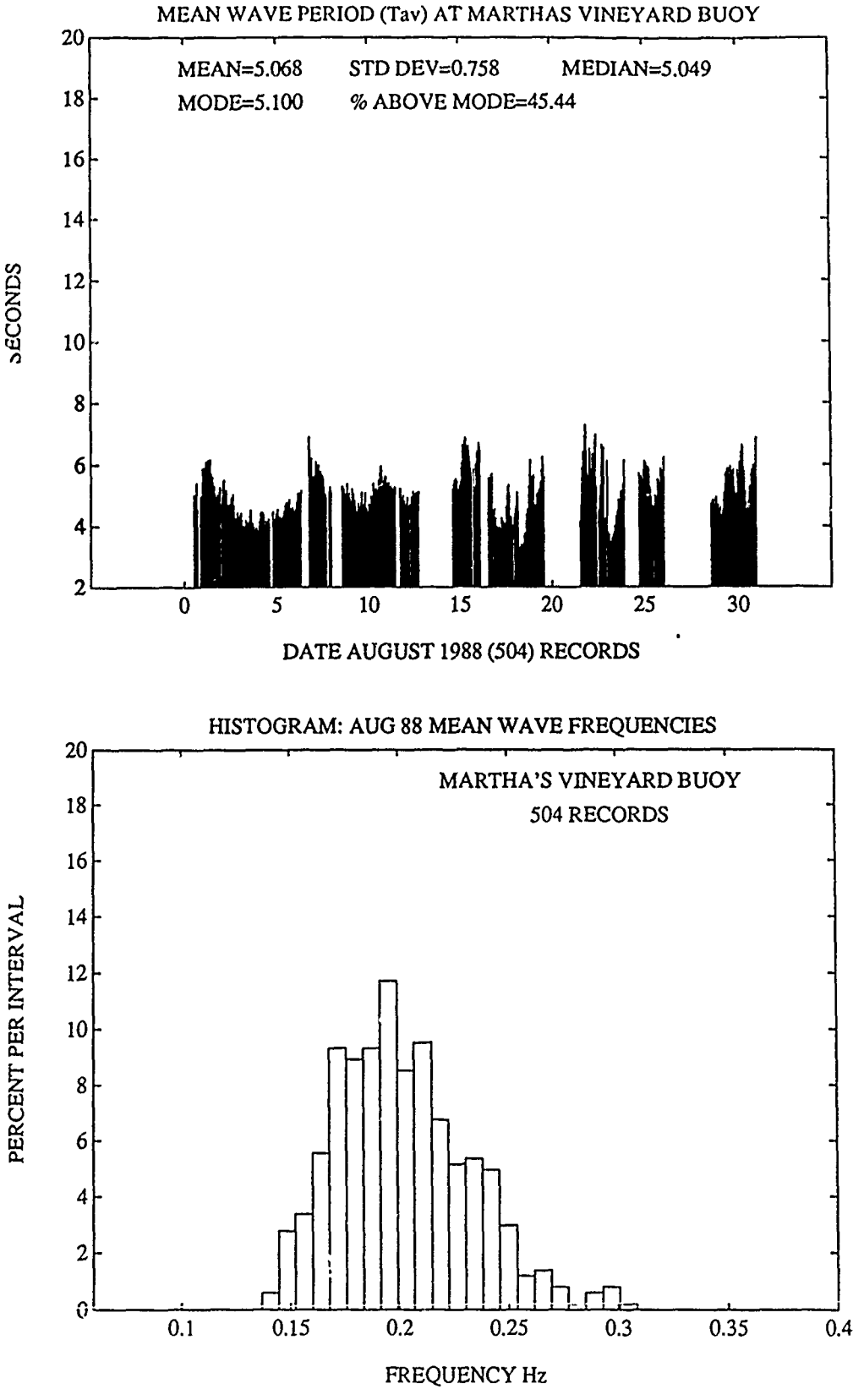
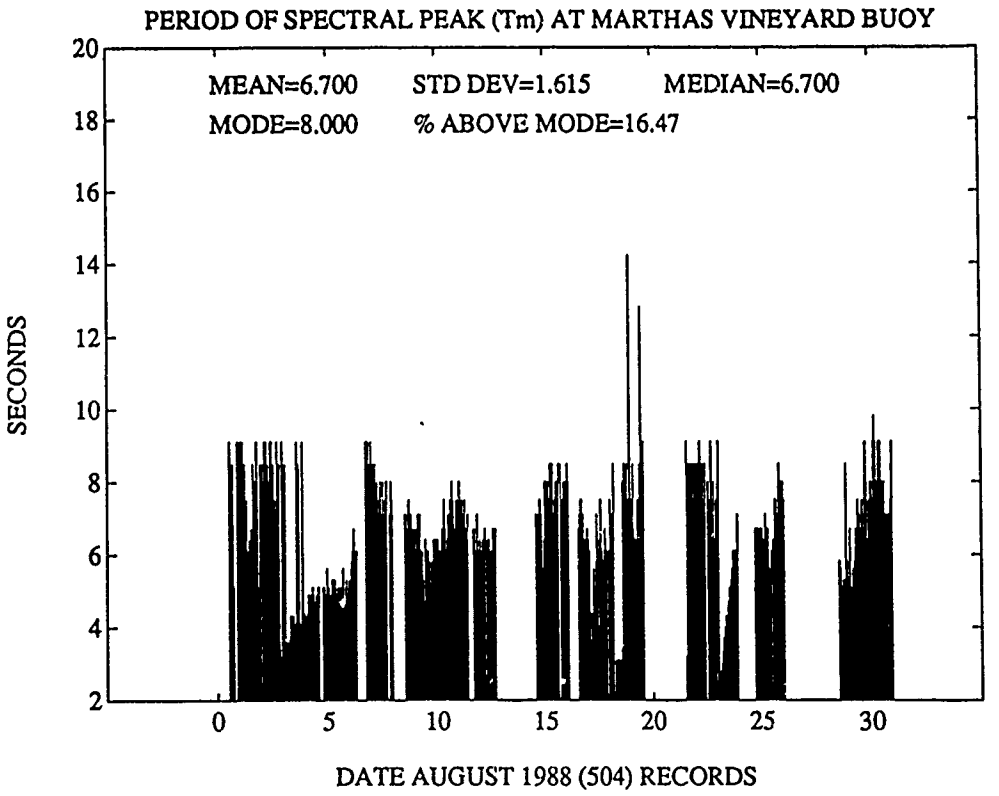


Figure 18: (continued) (c) Mean wave period time series, and (d) mean wave frequency distribution.



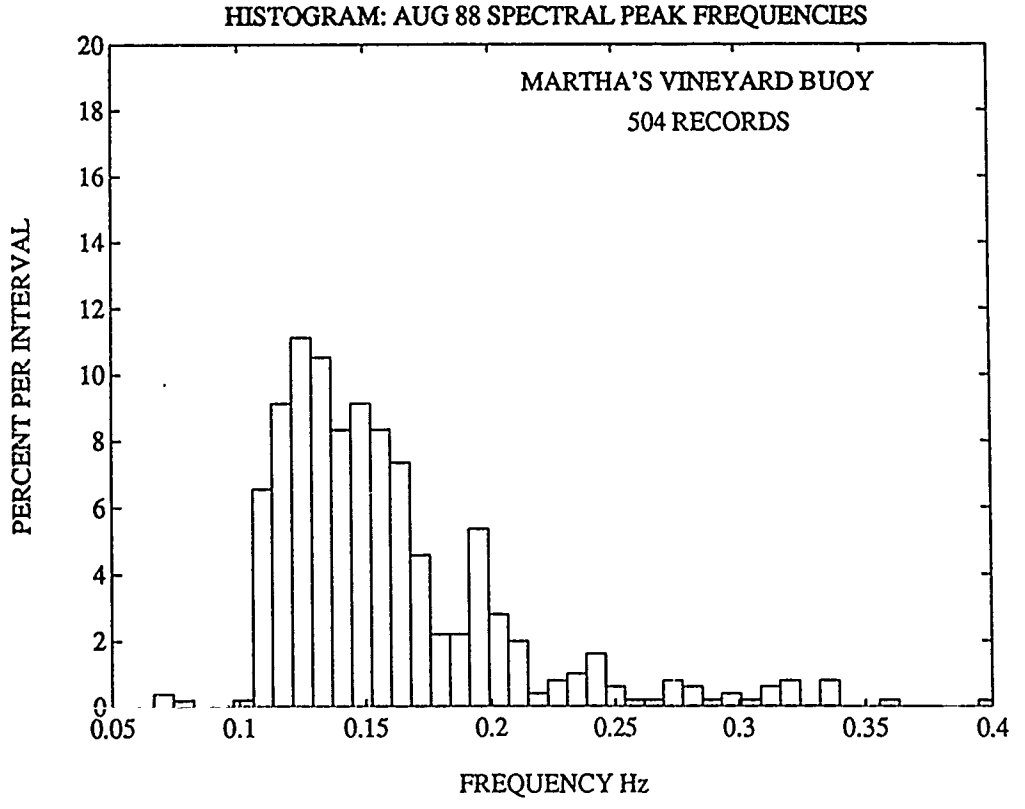
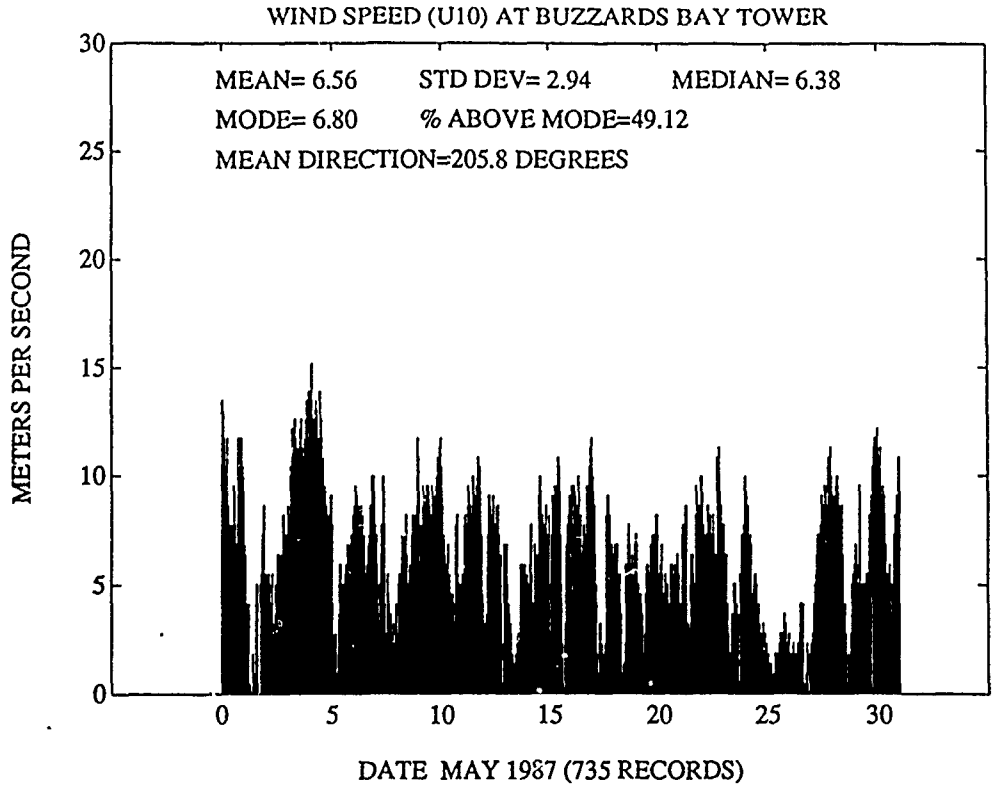


Figure 18: (continued) (e) Spectral peak period time series, and (f) spectral peak frequency distribution.



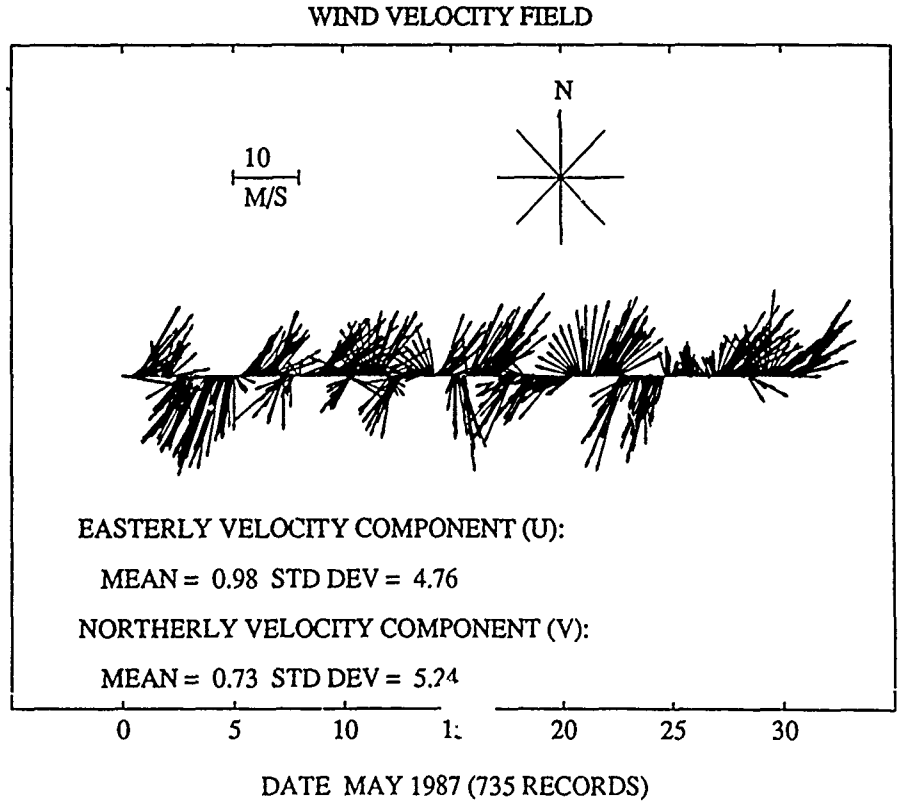
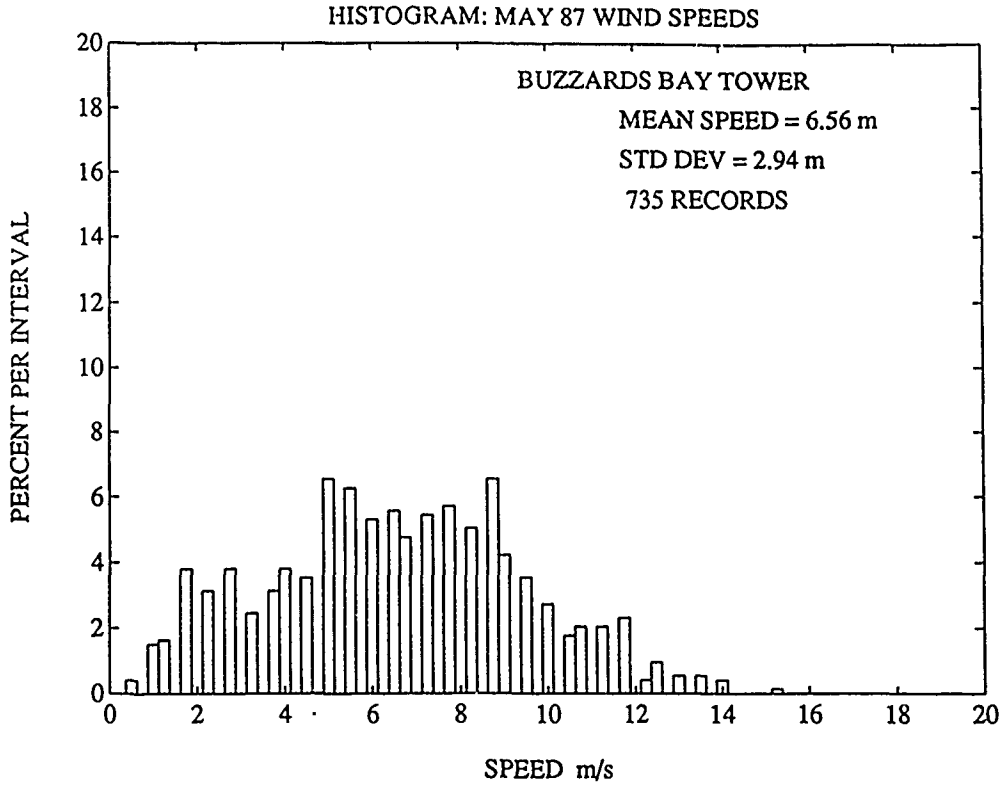


Figure 19: Wind speed and direction at Buzzards Bay Tower, May 1987. (a) Wind speed time series, and (b) wind velocity vector plot.



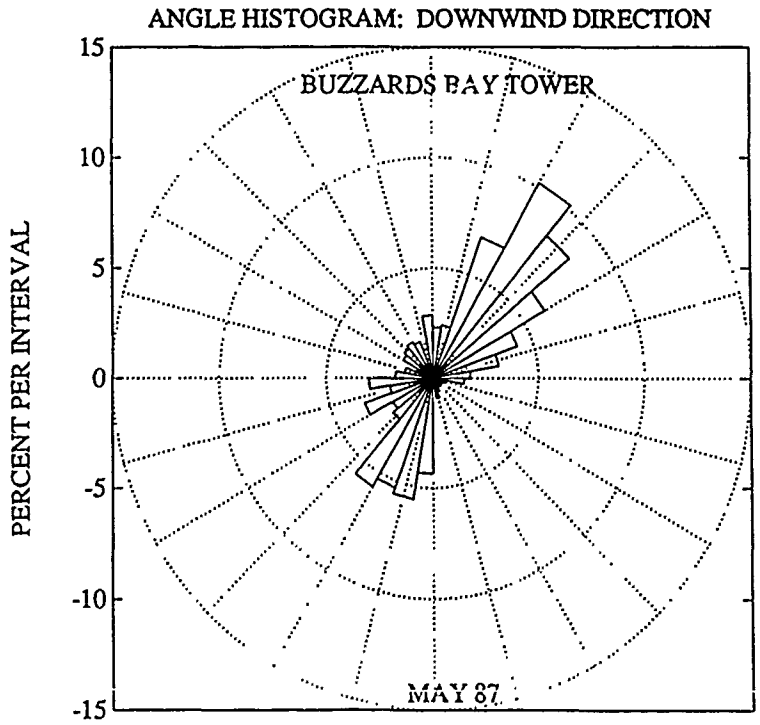
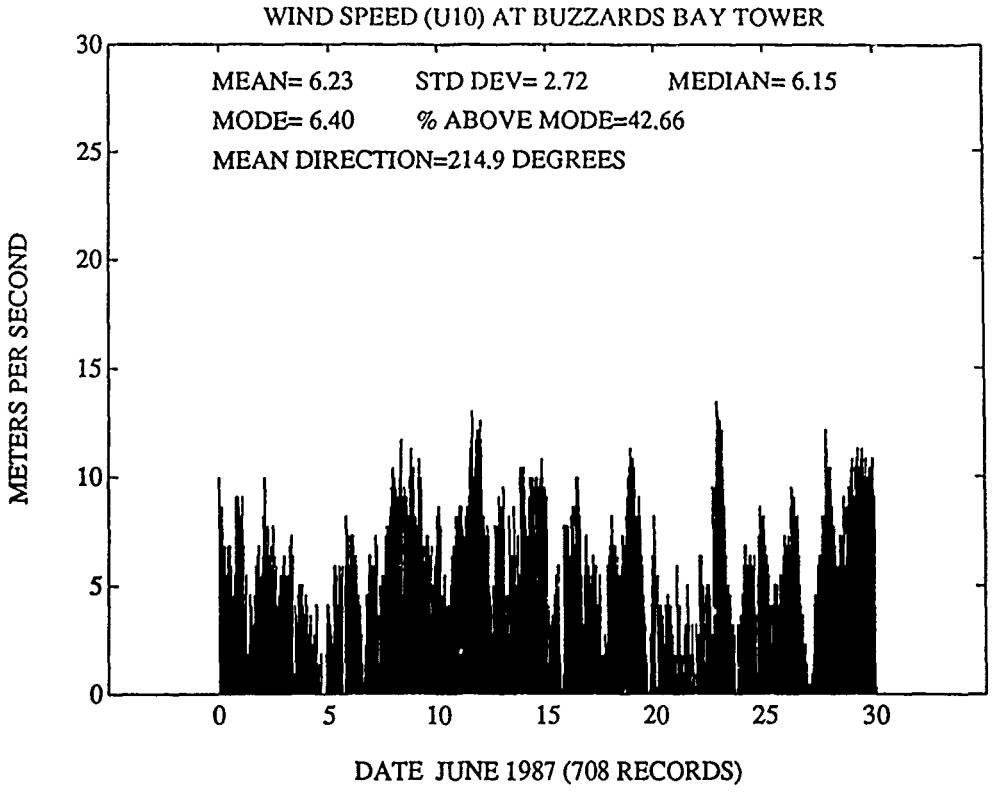


Figure 19: (continued) (c) Wind speed distribution, and (d) wind direction distribution.



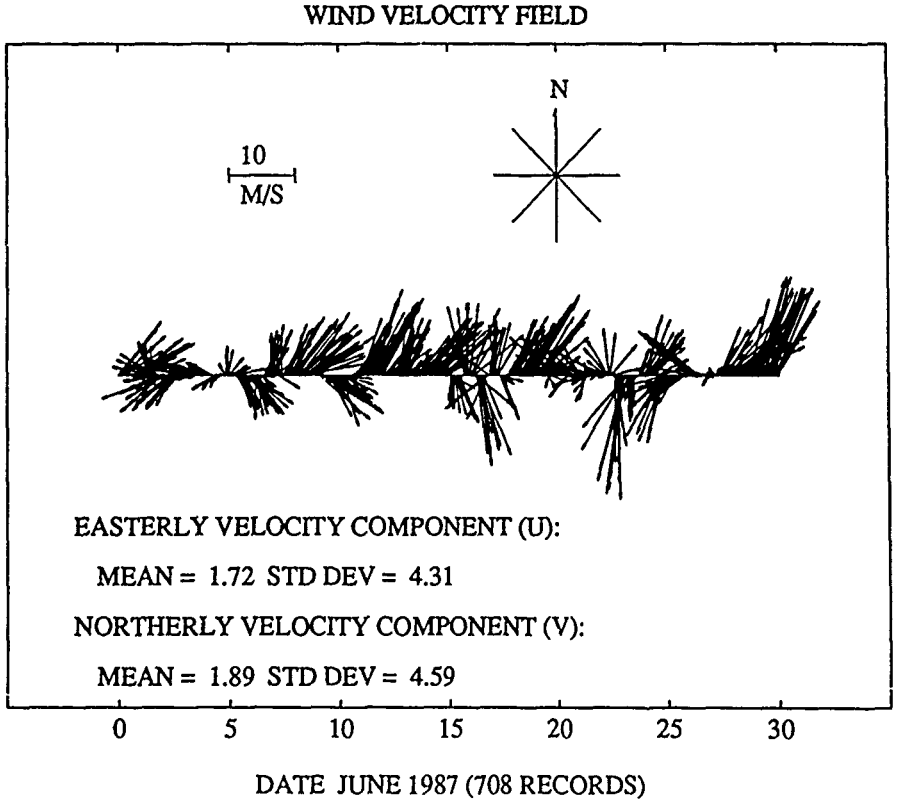
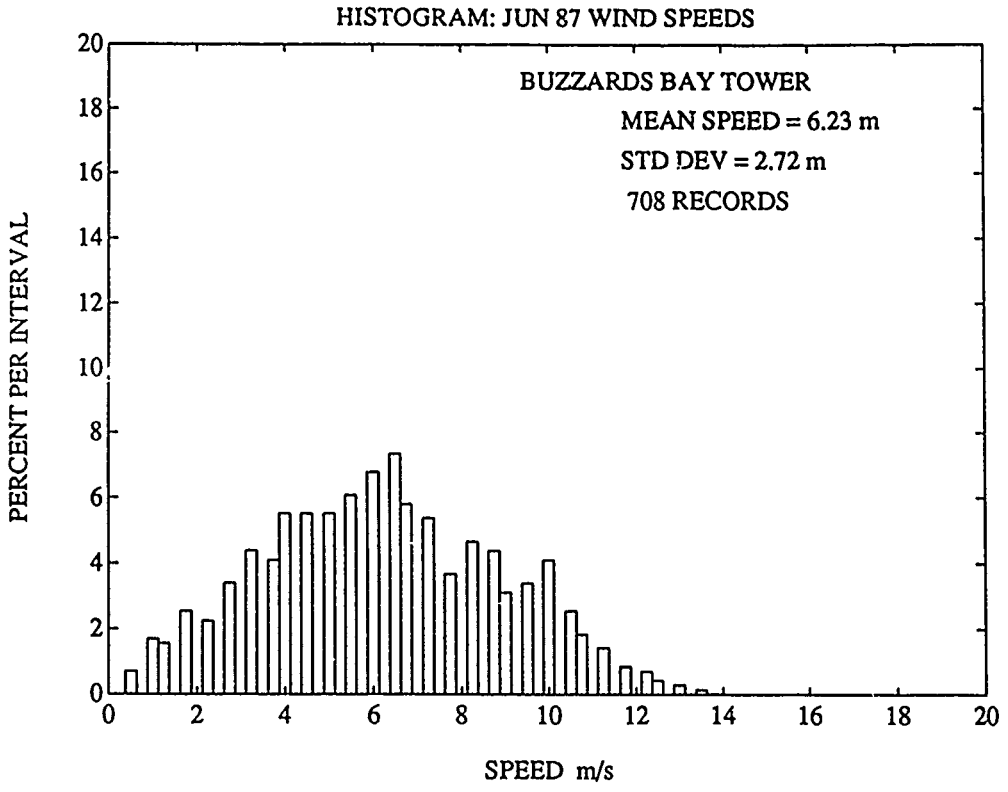


Figure 20: Wind speed and direction at Buzzards Bay Tower, June 1987. (a) Wind speed time series, and (b) wind velocity vector plot.



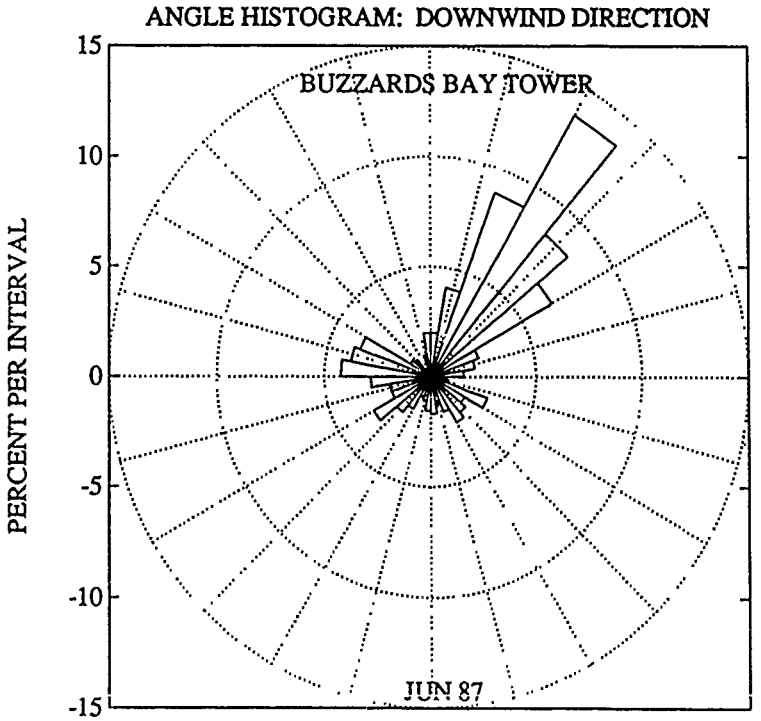
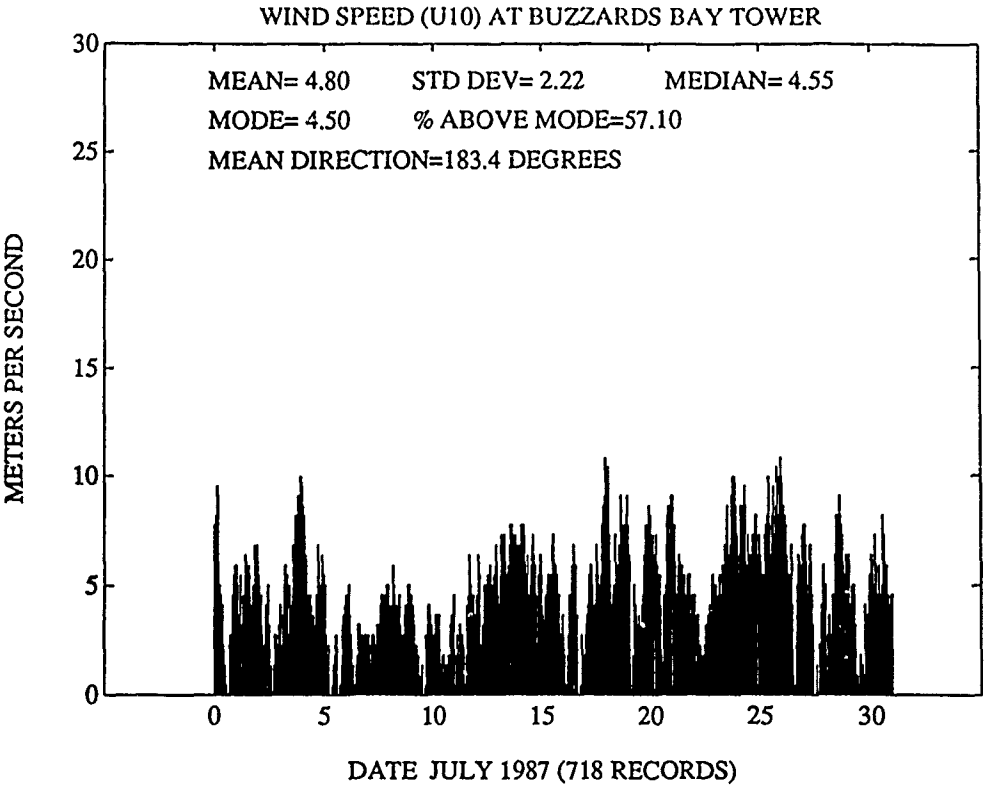


Figure 20: (continued) (c) Wind speed distribution, and (d) wind direction distribution.



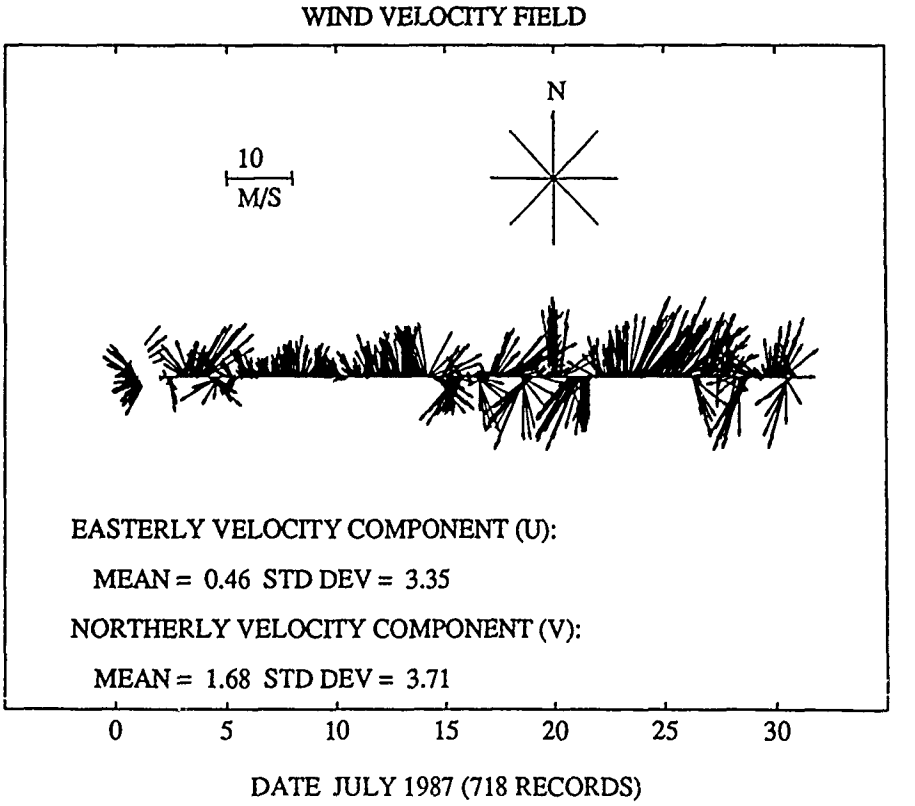
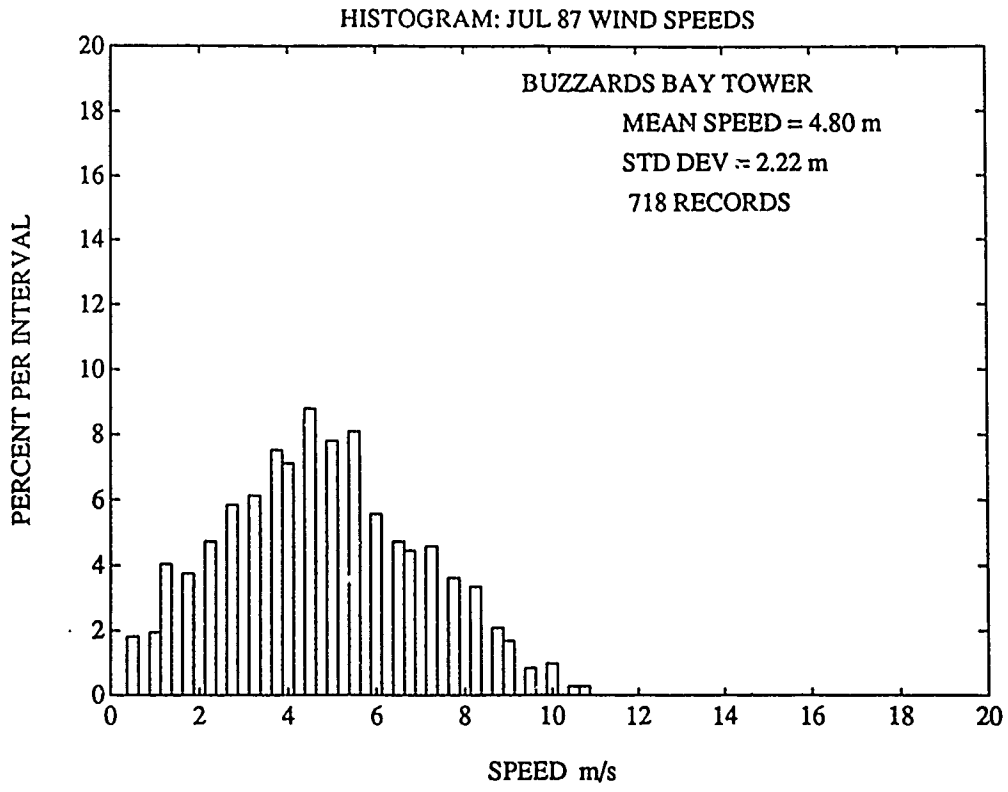


Figure 21: Wind speed and direction at Buzzards Bay Tower, July 1987. (a) Wind speed time series, and (b) wind velocity vector plot.



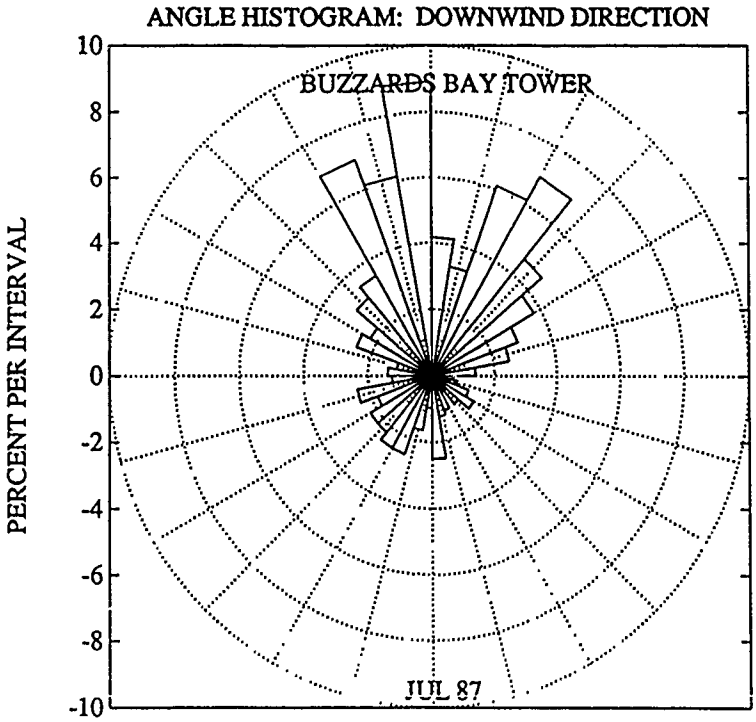
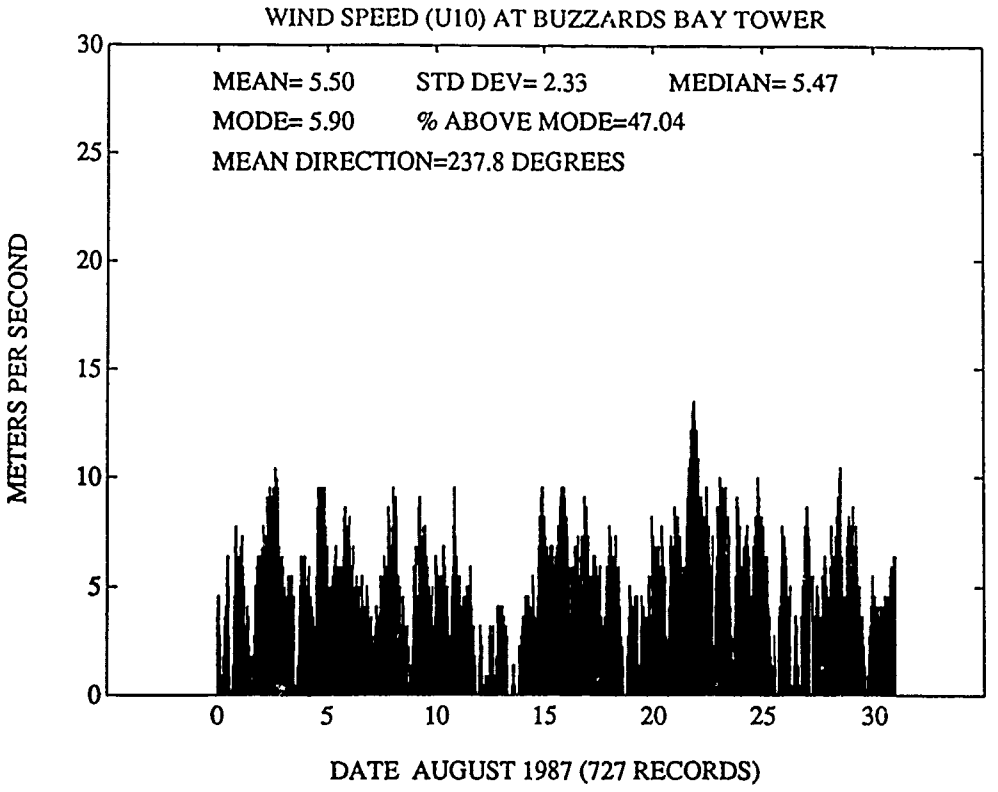


Figure 21: (continued) (c) Wind speed distribution, and (d) wind direction distribution.



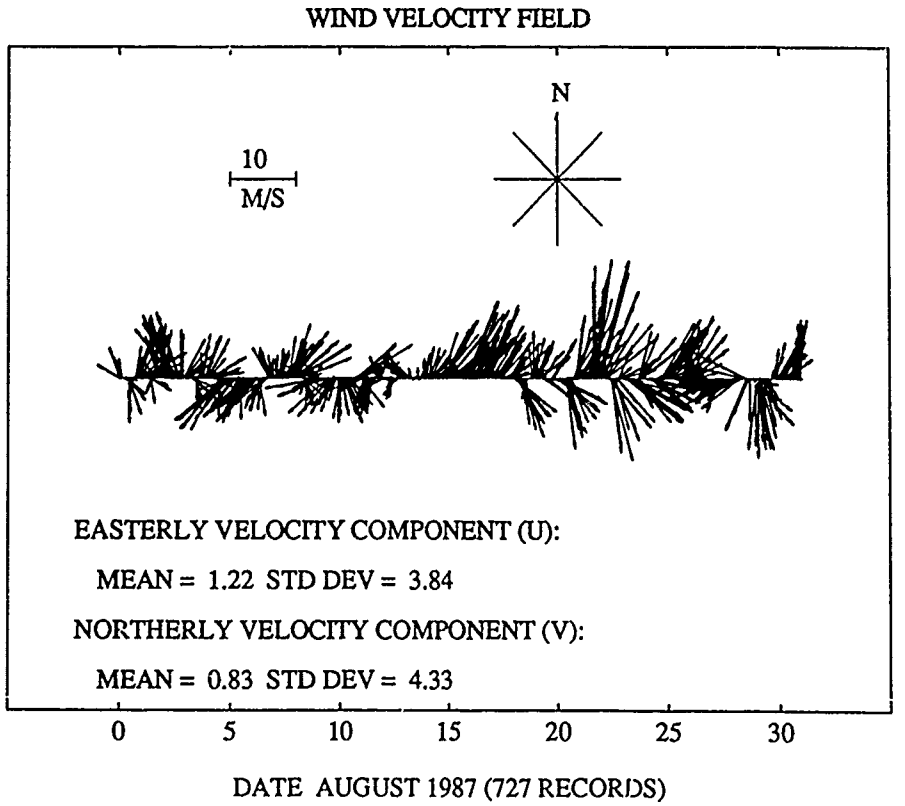
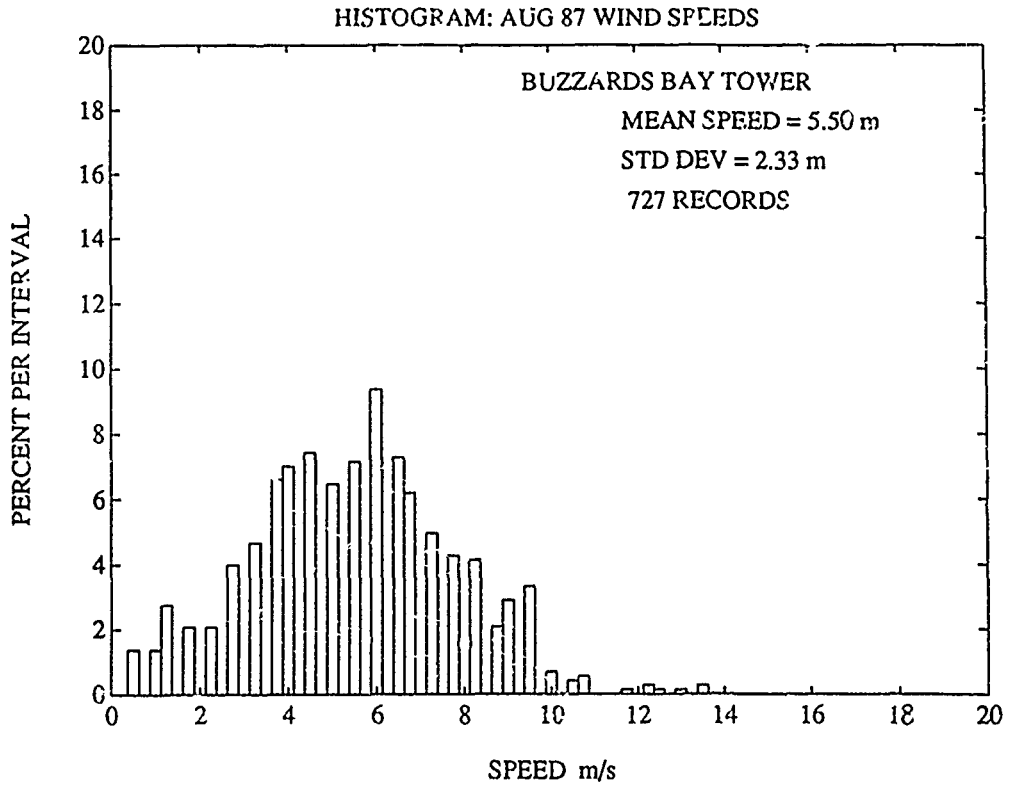


Figure 22: Wind speed and direction at Buzzards Bay Tower, August 1987. (a) Wind speed time series, and (b) wind velocity vector plot.



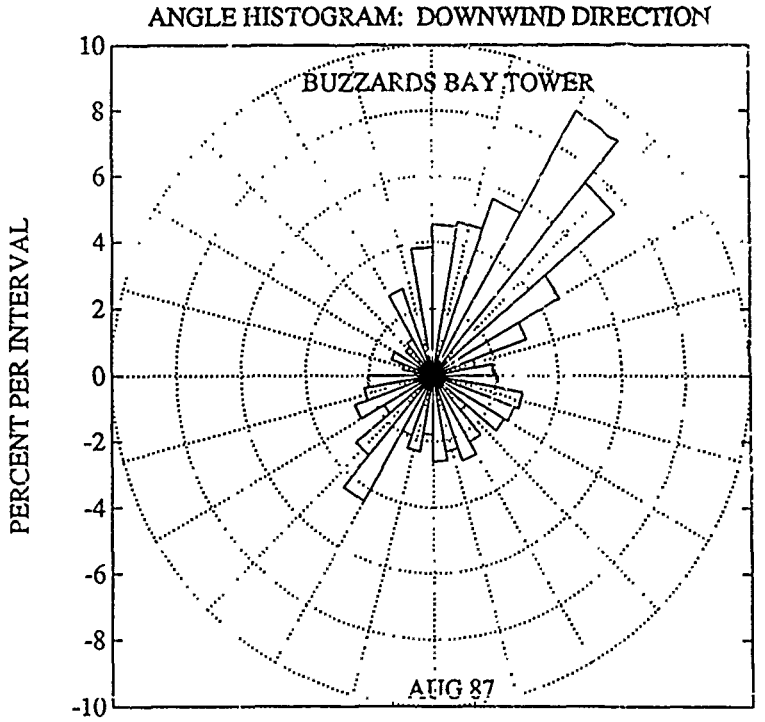
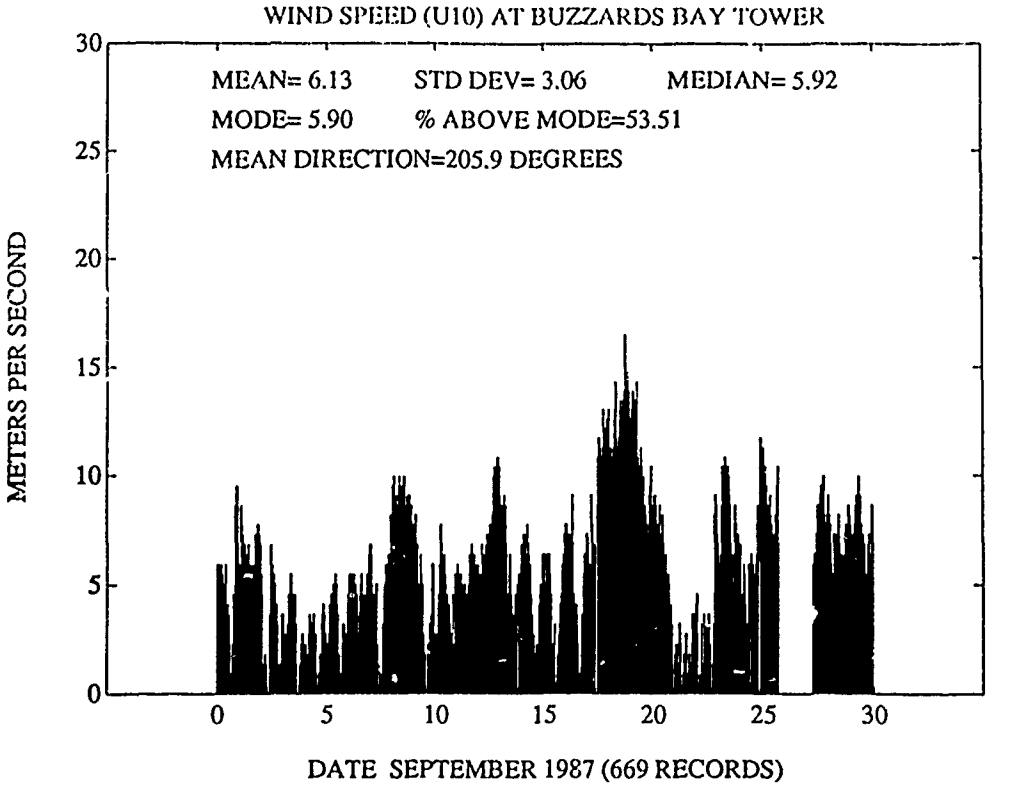


Figure 22: (continued) (c) Wind speed distribution, and (d) wind direction distribution.



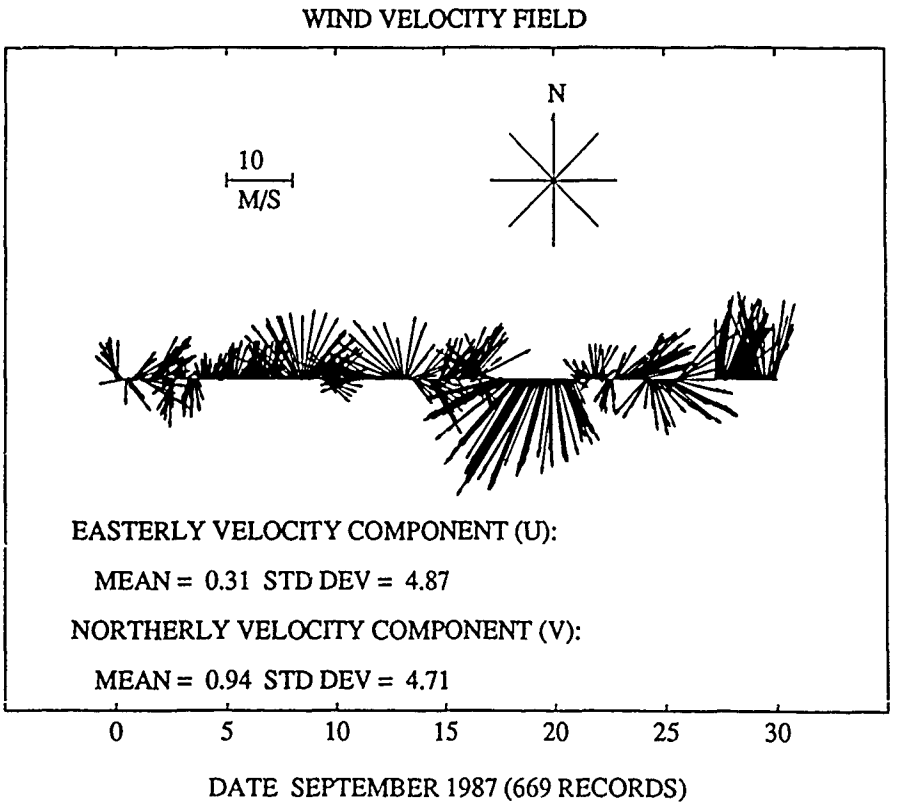
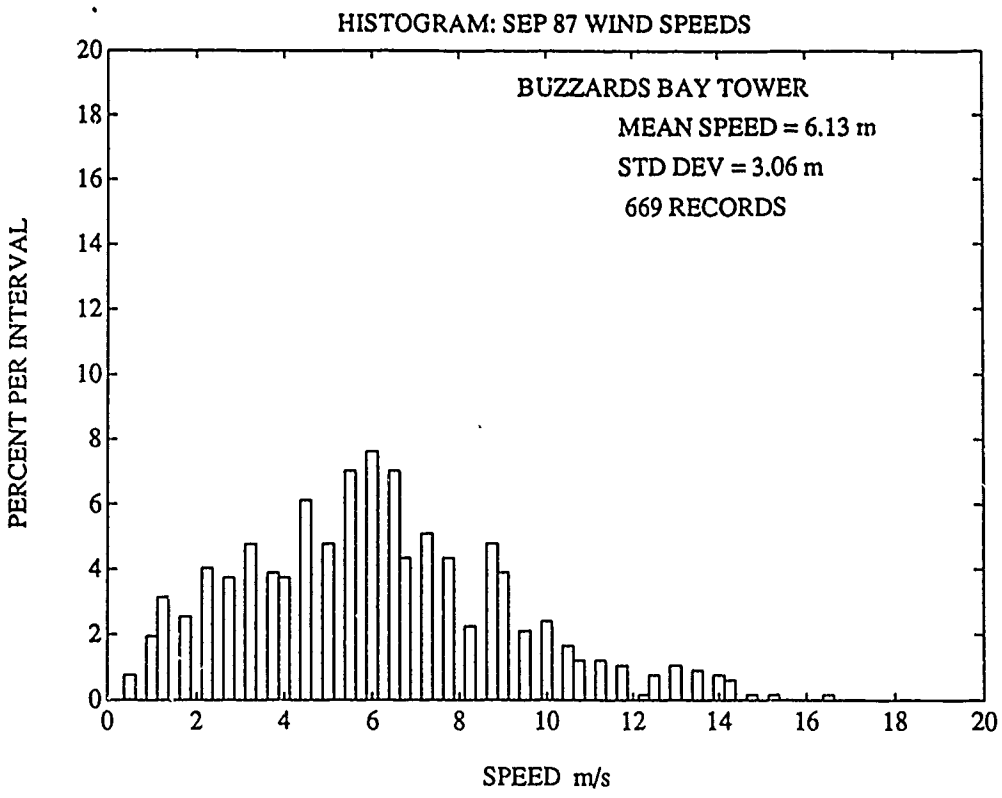


Figure 23: Wind speed and direction at Buzzards Bay Tower, September 1987. (a) Wind speed time series, and (b) wind velocity vector plot.



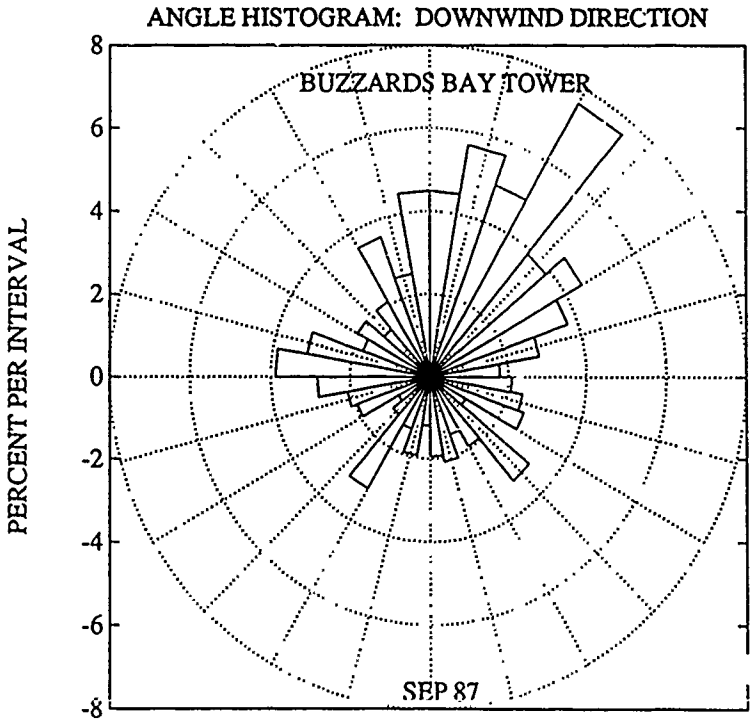
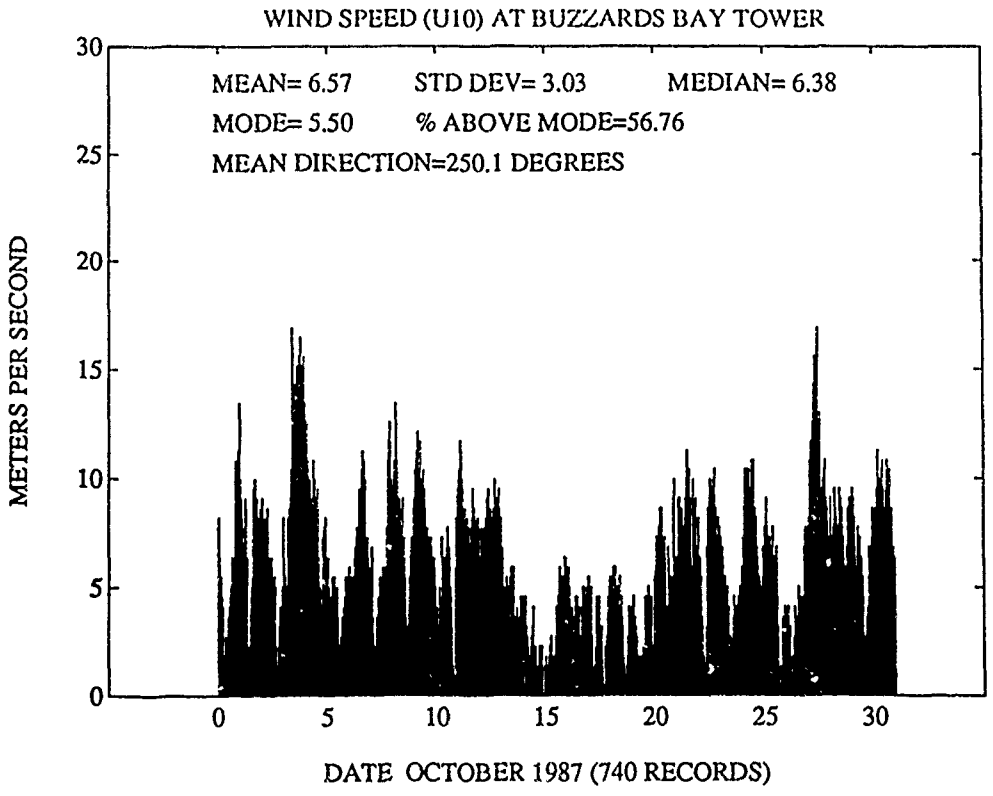


Figure 23: (continued) (c) Wind speed distribution, and (d) wind direction distribution.



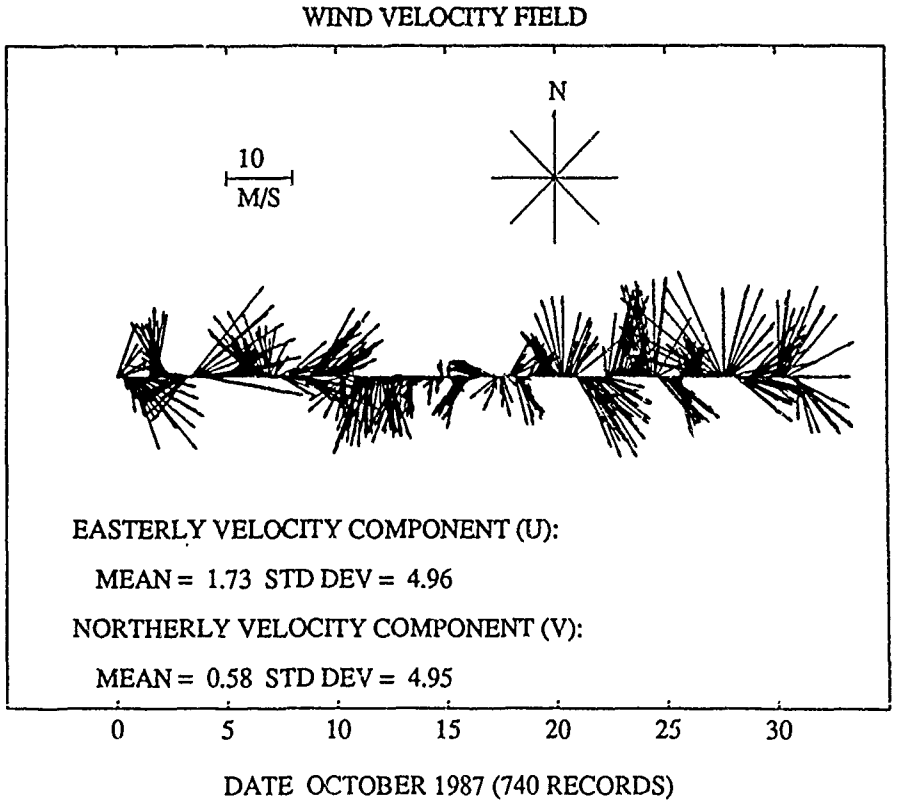
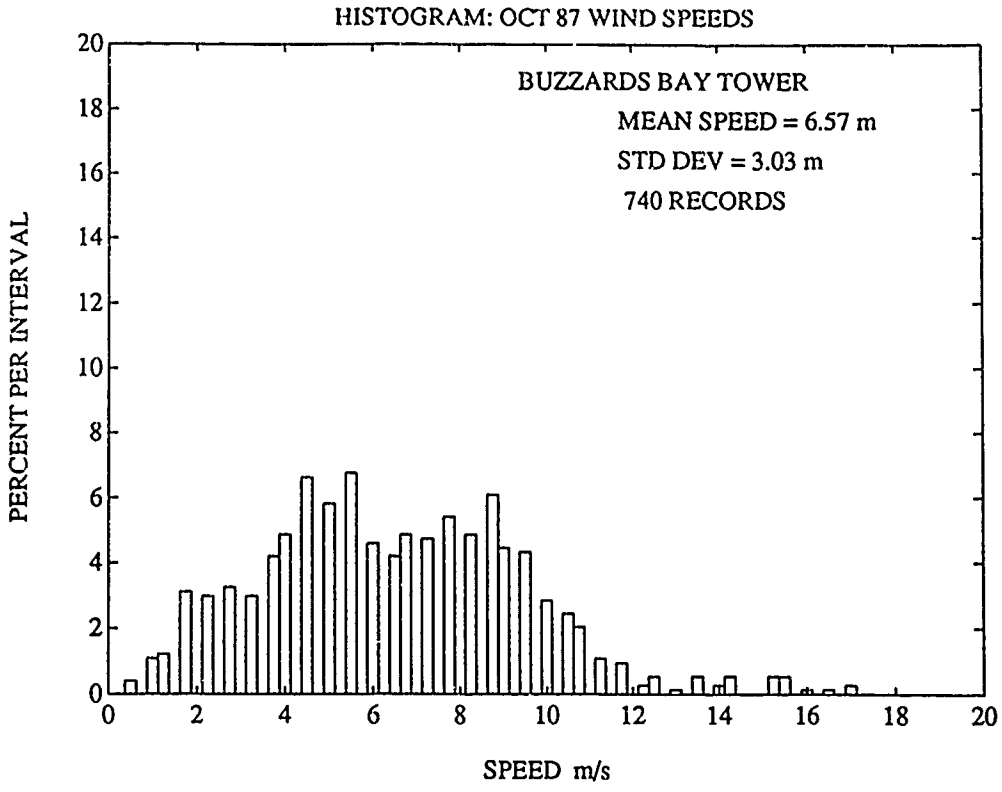


Figure 24: Wind speed and direction at Buzzards Bay Tower, October 1987. (a) Wind speed time series, and (b) wind velocity vector plot.



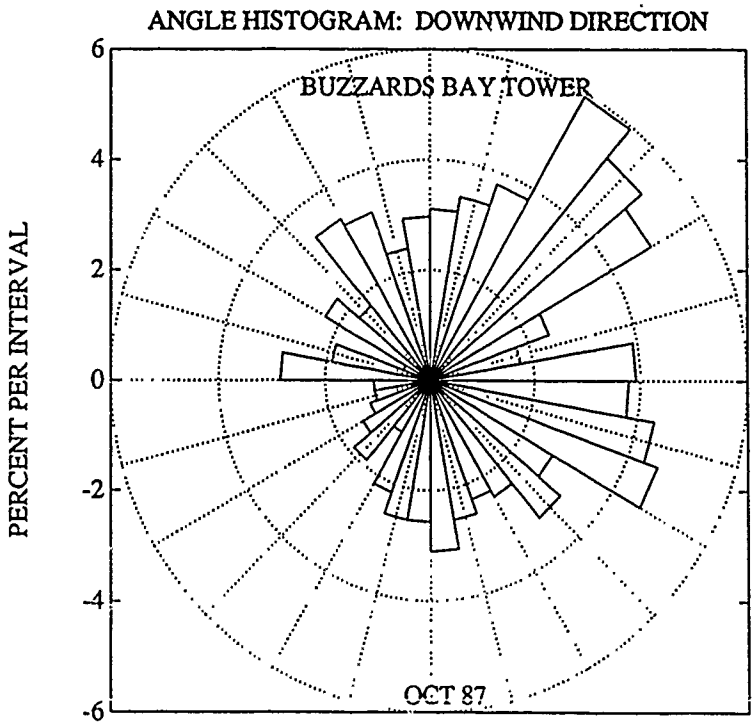
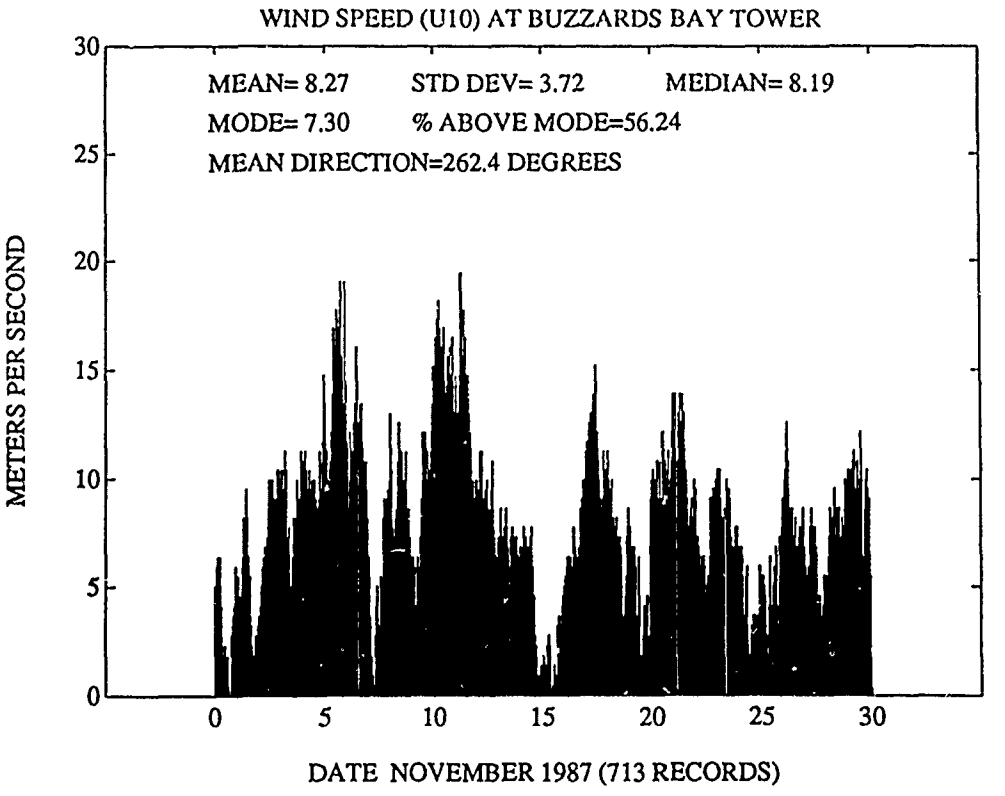


Figure 24: (continued) (c) Wind speed distribution, and (d) wind direction distribution.



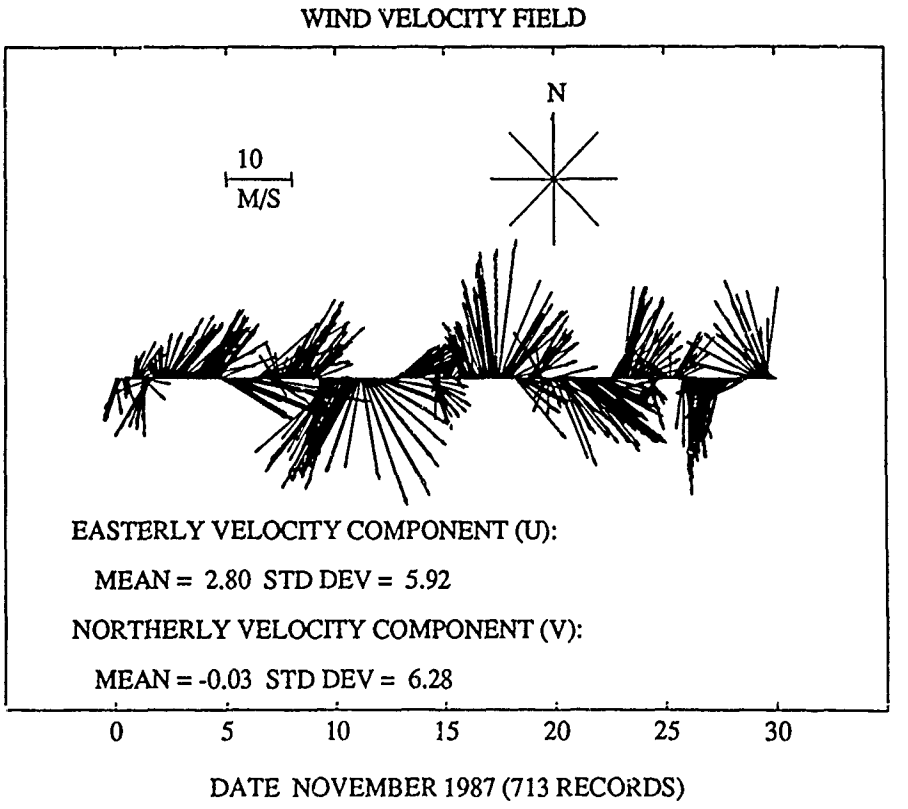
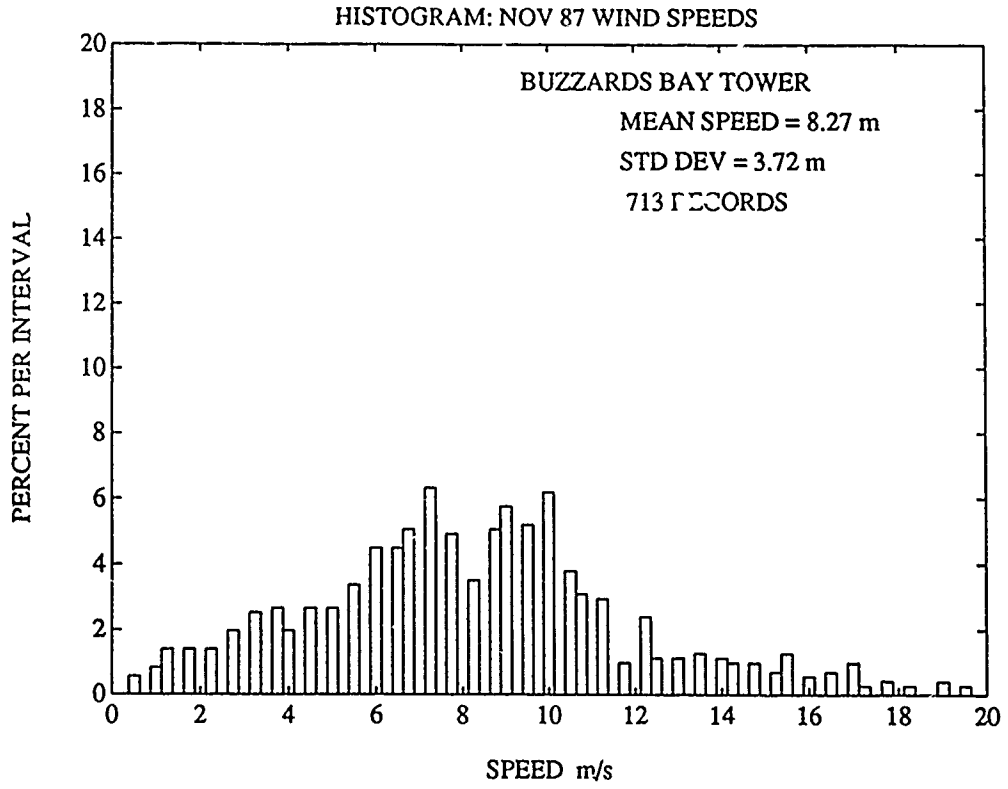


Figure 25: Wind speed and direction at Buzzards Bay Tower, November 1987. (a) Wind speed time series, and (b) wind velocity vector plot.



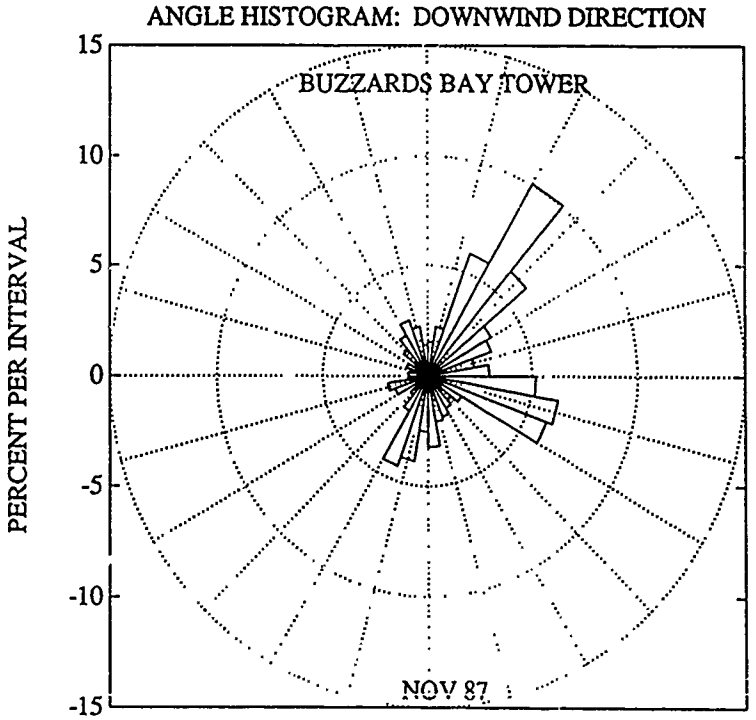
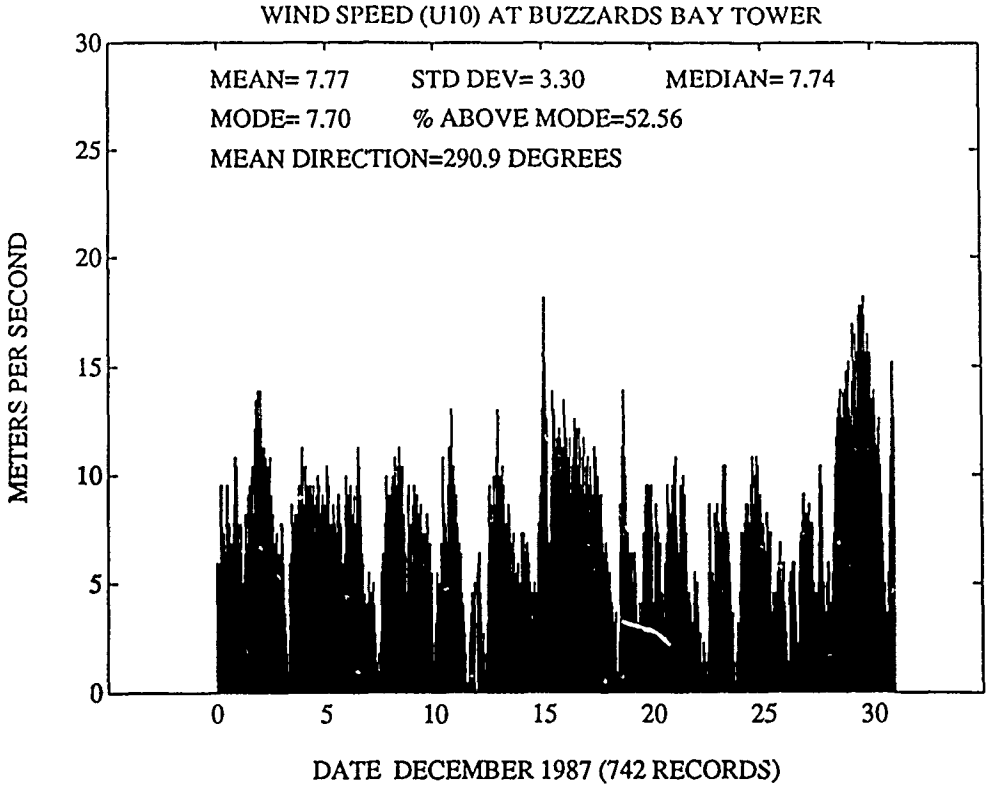


Figure 25: (continued) (c) Wind speed distribution, and (d) wind direction distribution.



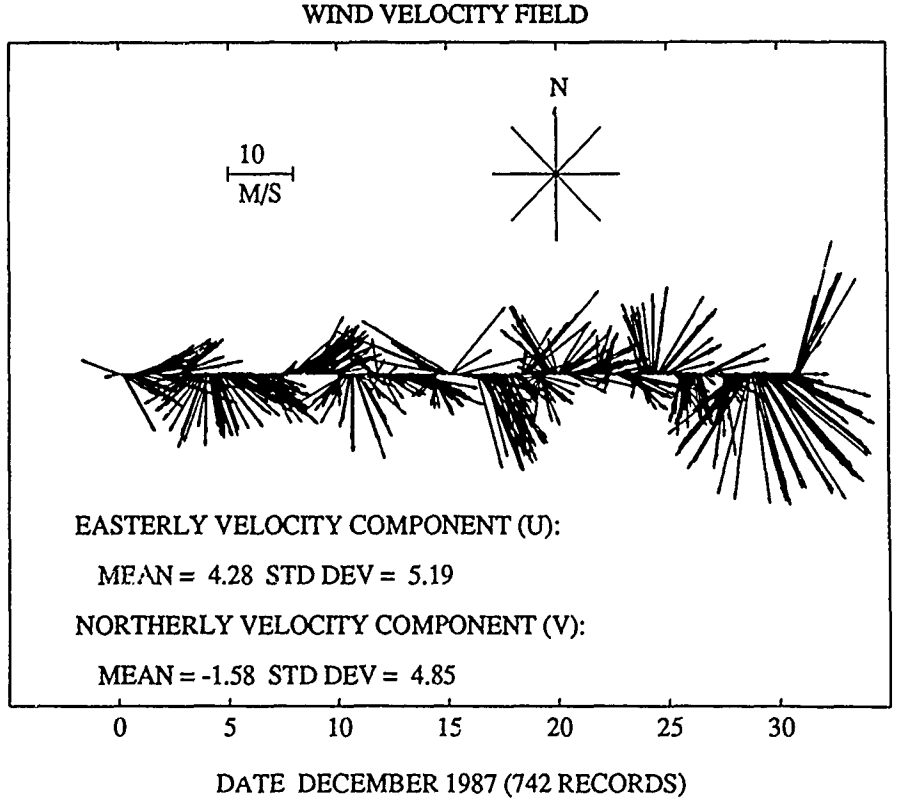
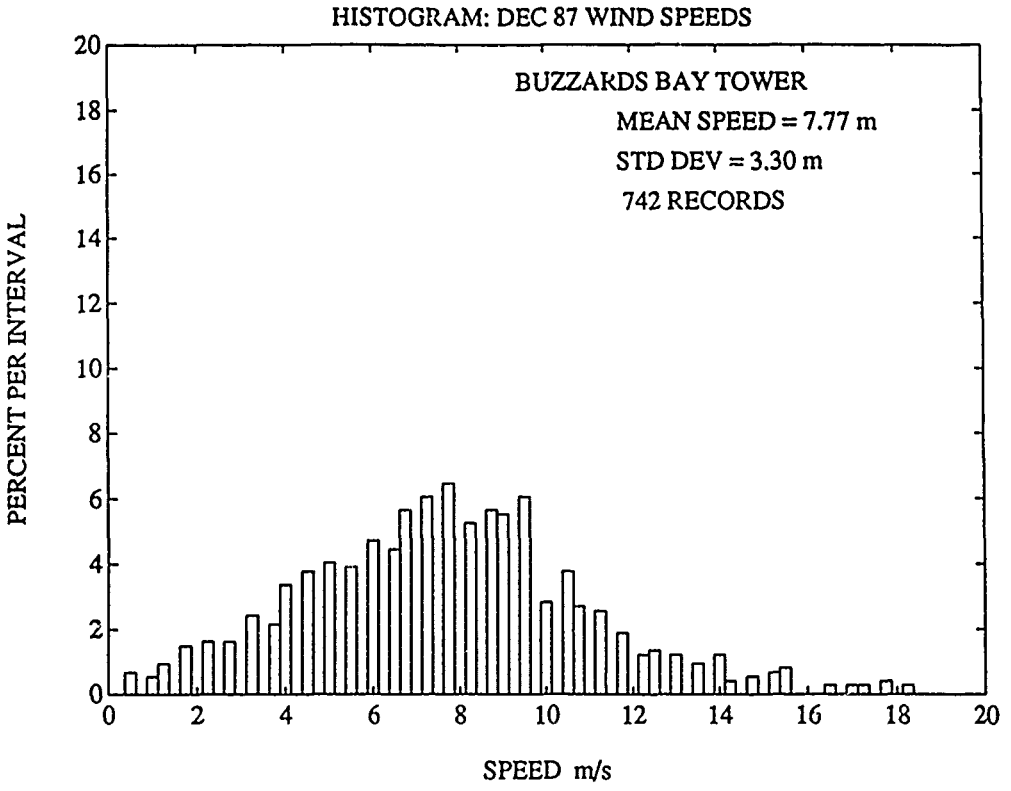


Figure 26: Wind speed and direction at Buzzards Bay Tower, December 1987. (a) Wind speed time series, and (b) wind velocity vector plot.



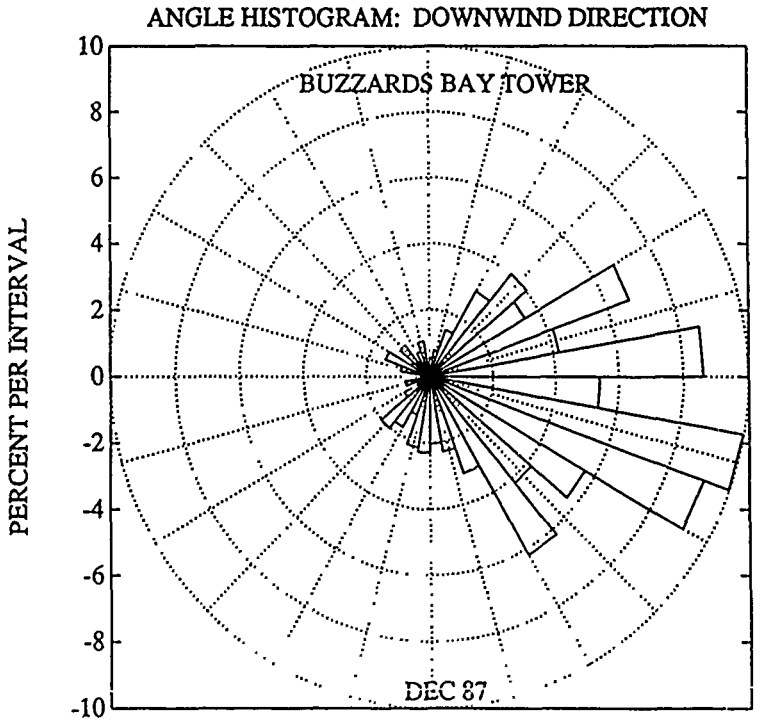
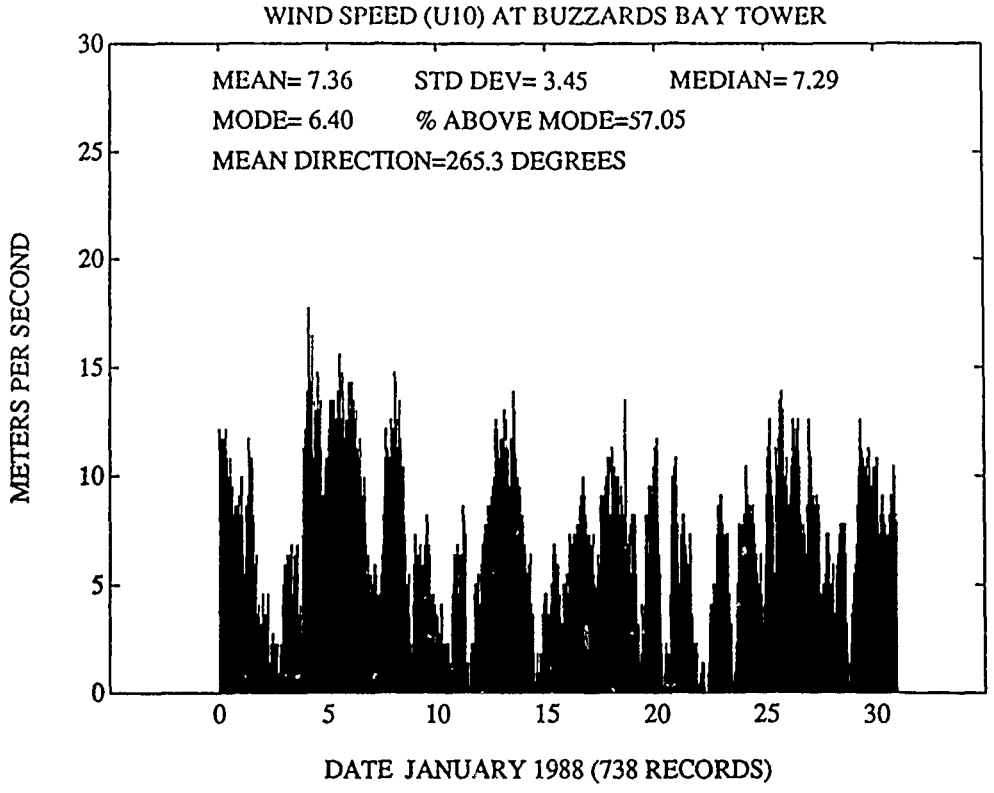


Figure 26: (continued) (c) Wind speed distribution, and (d) wind direction distribution.



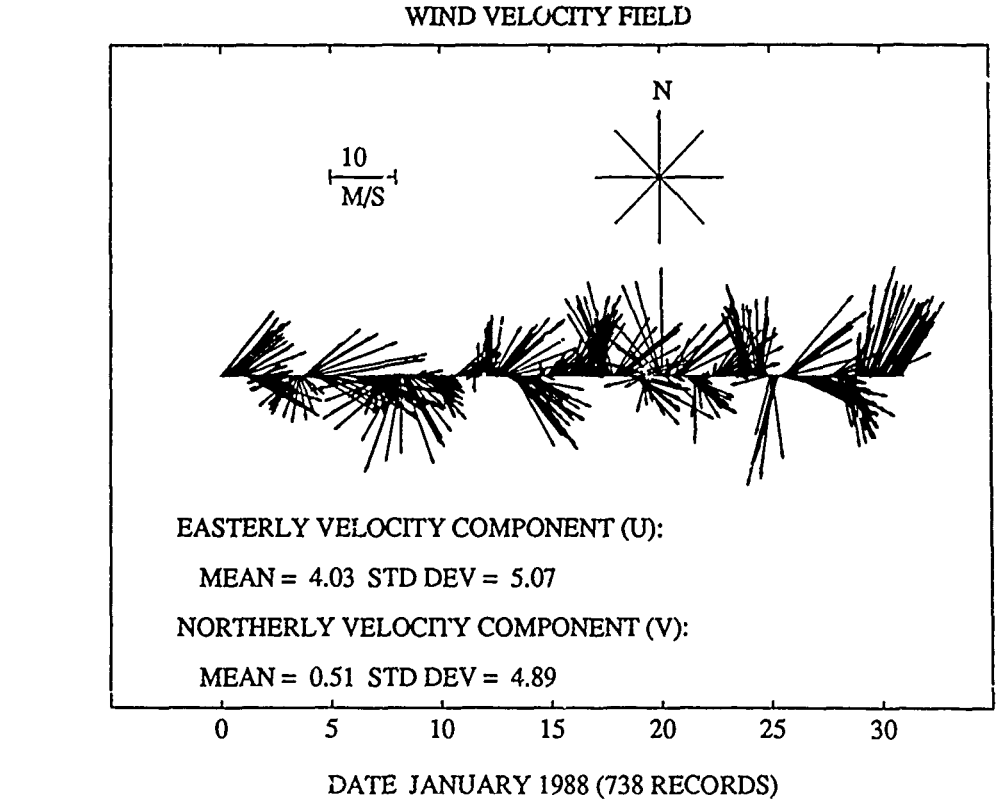
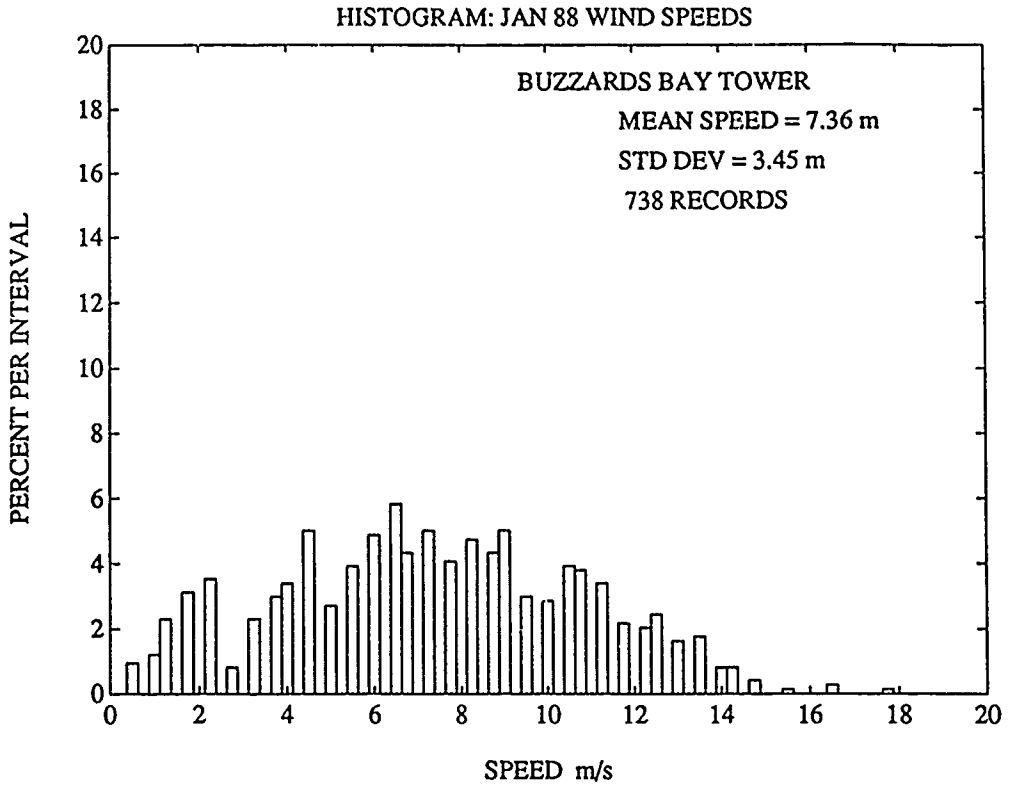


Figure 27: Wind speed and direction at Buzzards Bay Tower, January 1988. (a) Wind speed time series, and (b) wind velocity vector plot.



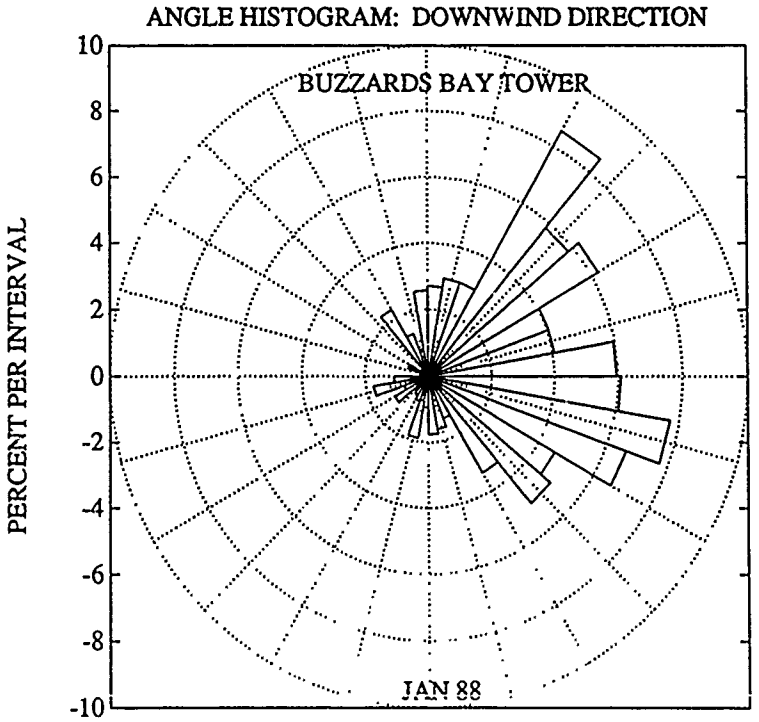
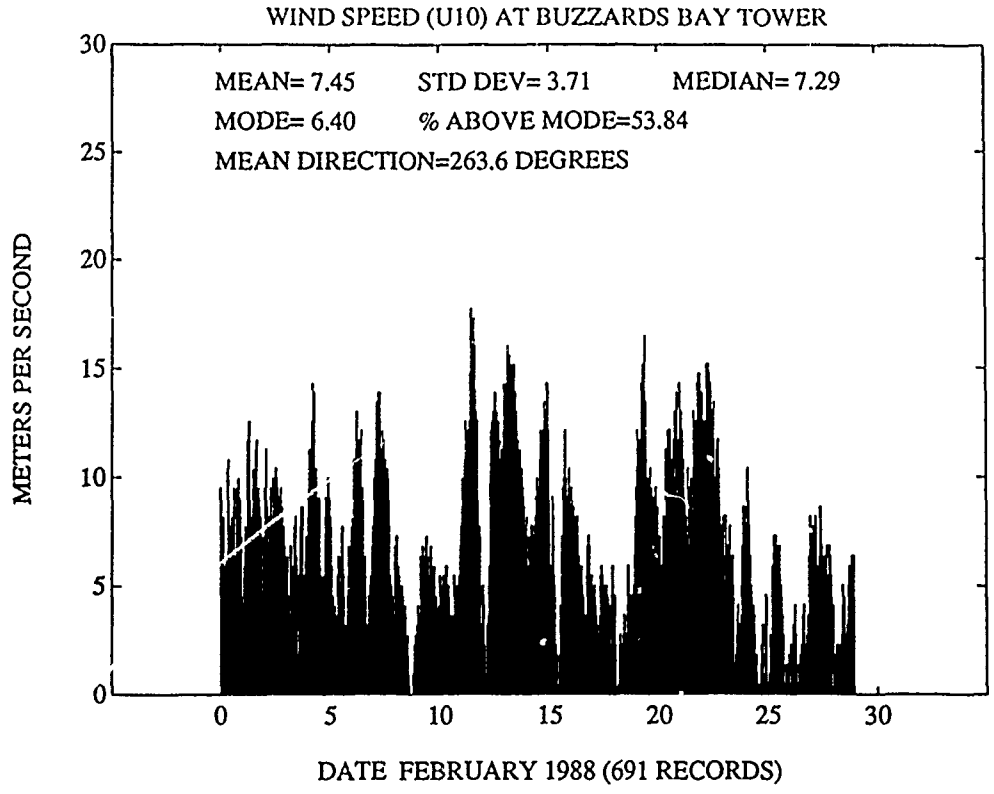


Figure 27: (continued) (c) Wind speed distribution, and (d) wind direction distribution.



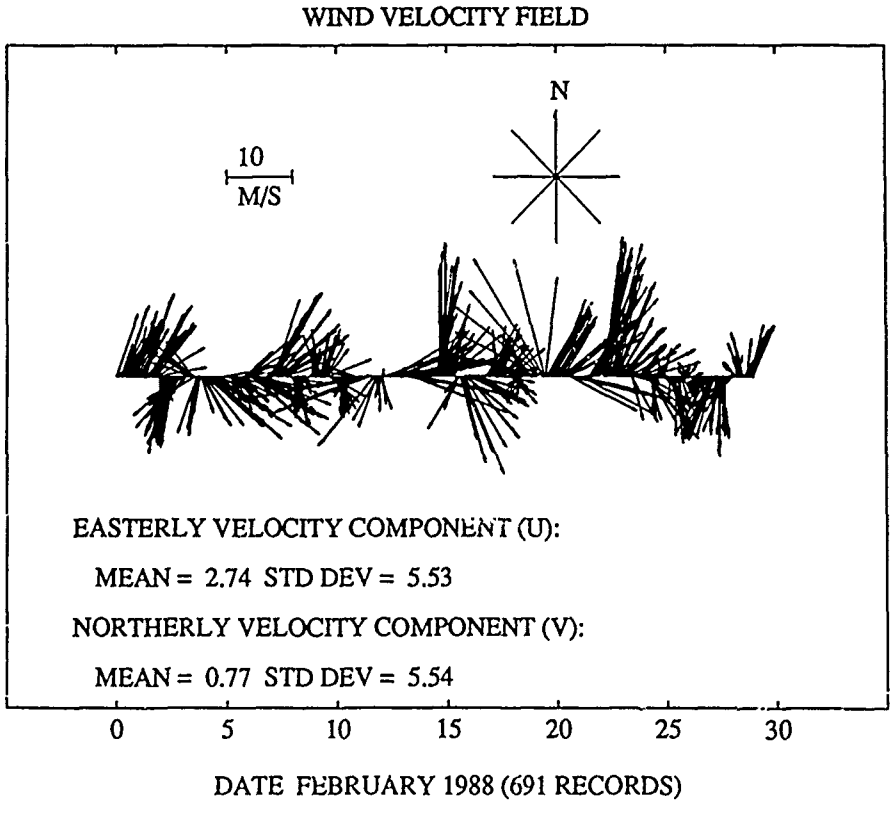
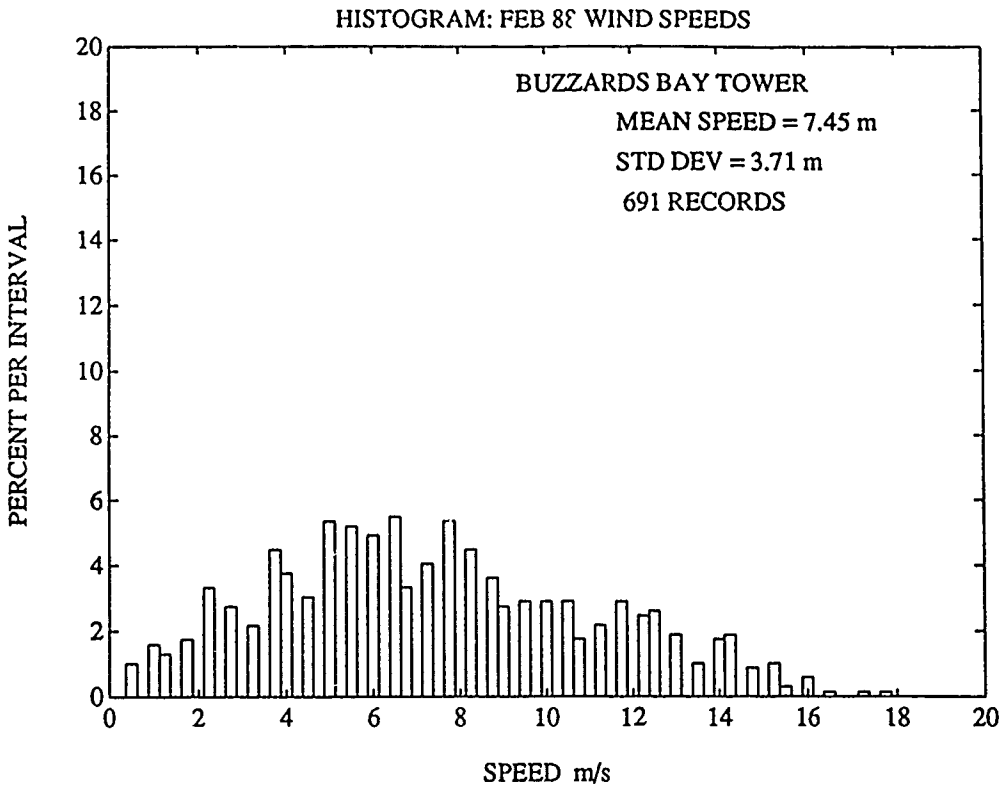


Figure 28: Wind speed and direction at Buzzards Bay Tower, February 1988. (a) Wind speed time series, and (b) wind velocity vector plot.



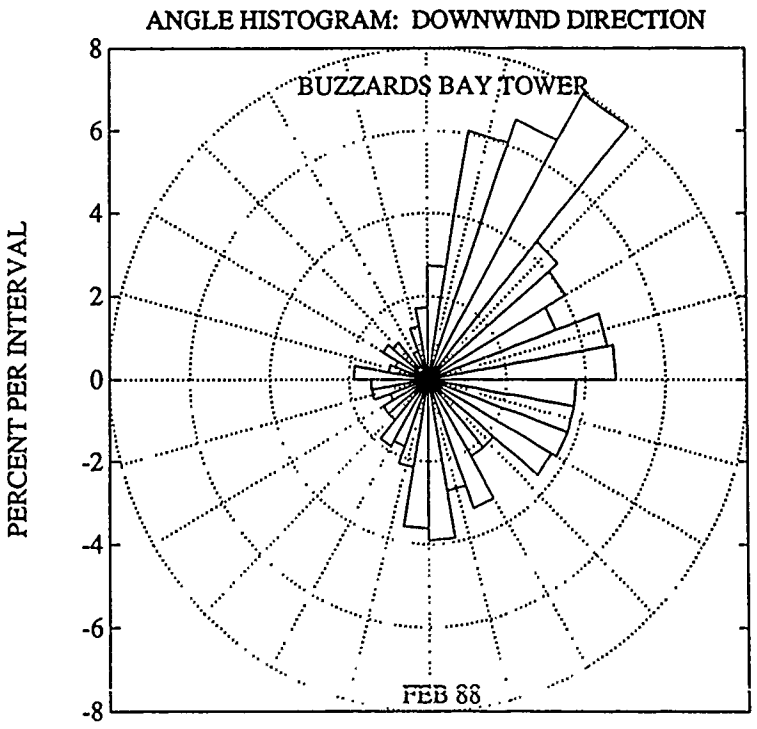
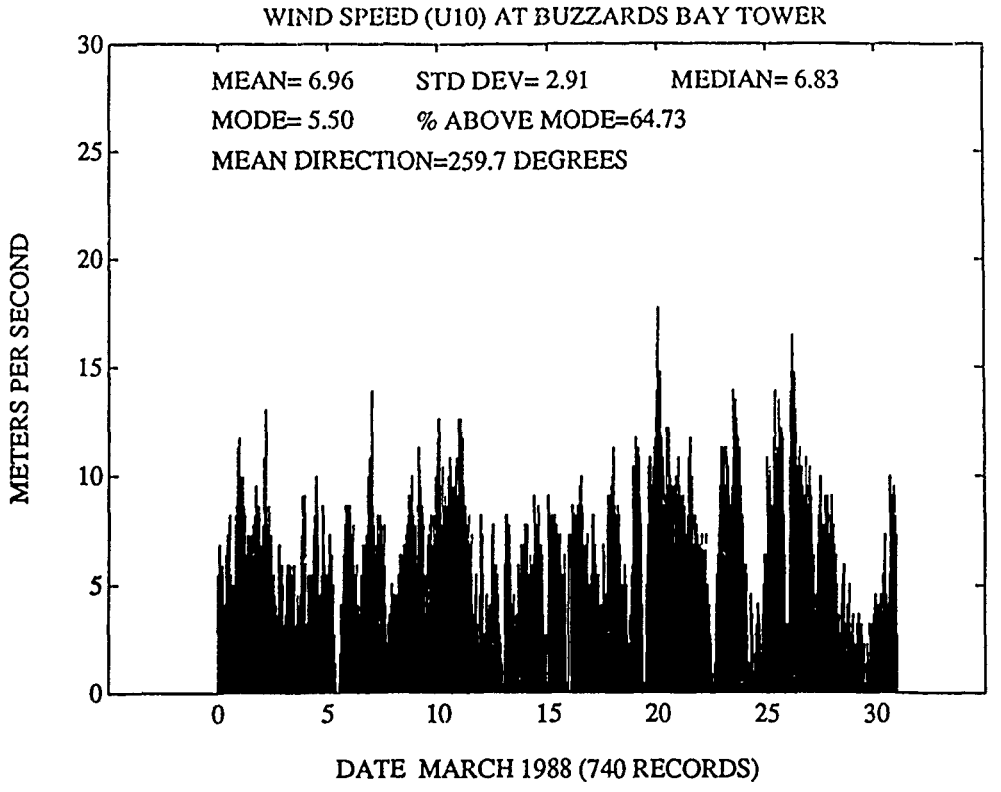


Figure 28: (continued) (c) Wind speed distribution, and (d) wind direction distribution.



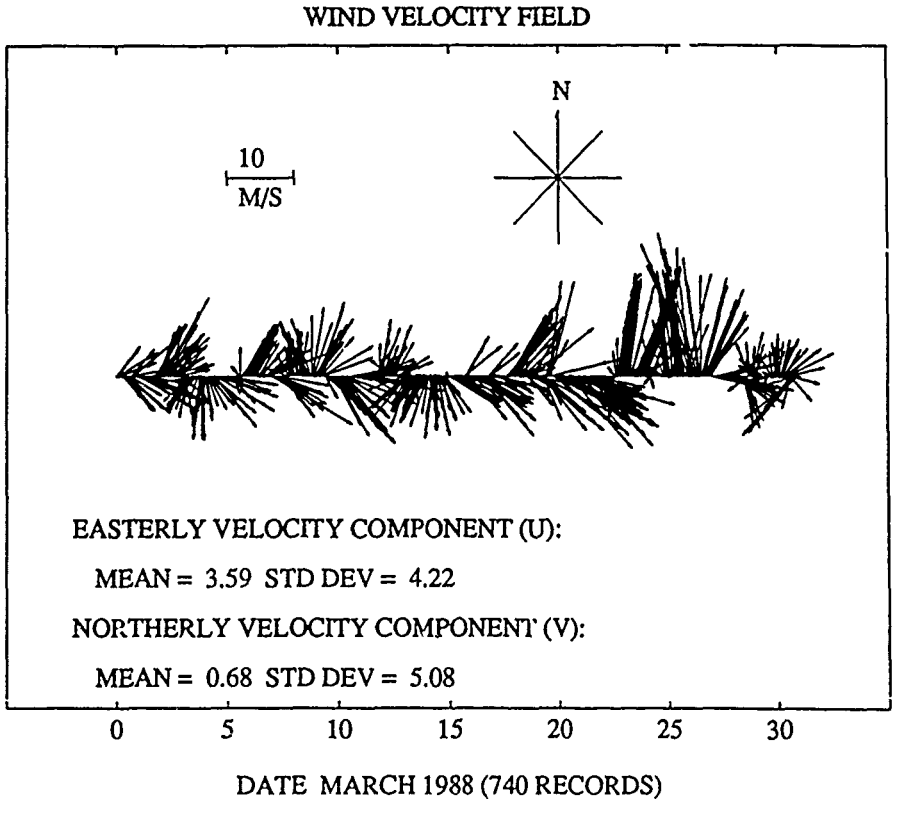
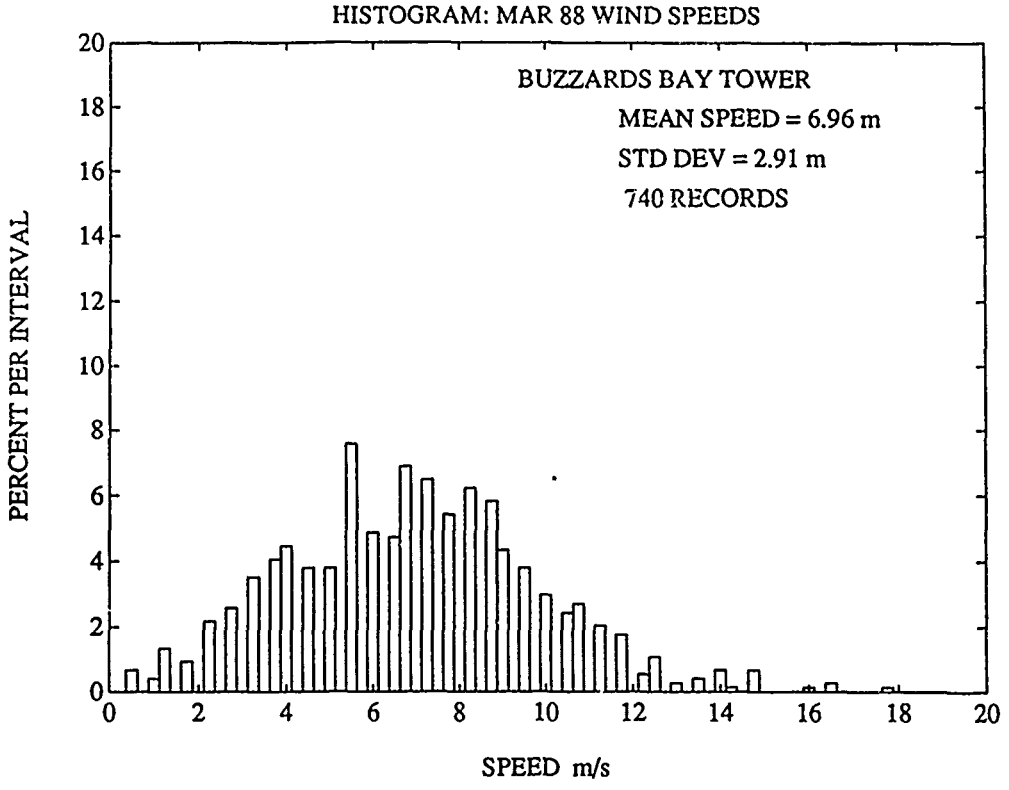


Figure 29: Wind speed and direction at Buzzards Bay Tower, March 1988. (a) Wind speed time series, and (b) wind velocity vector plot.



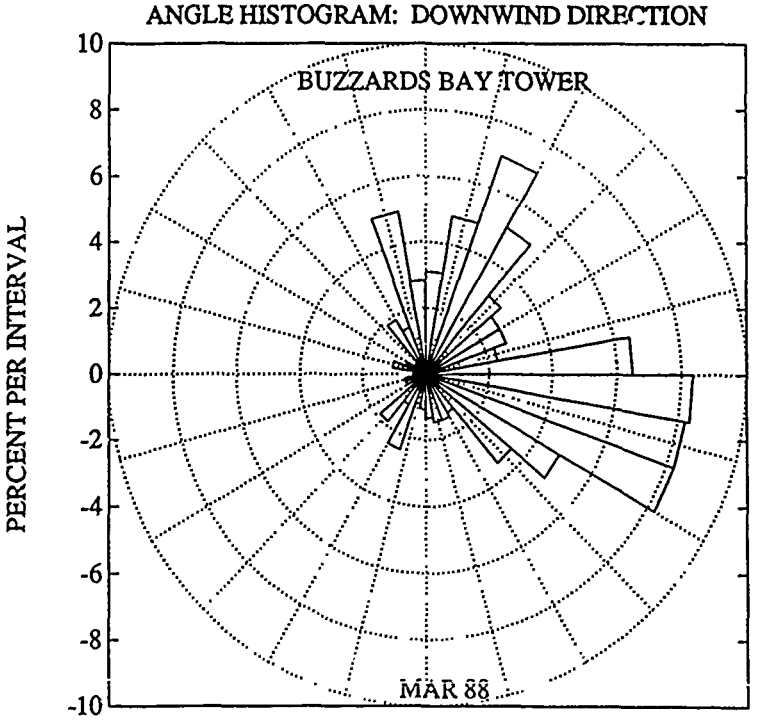
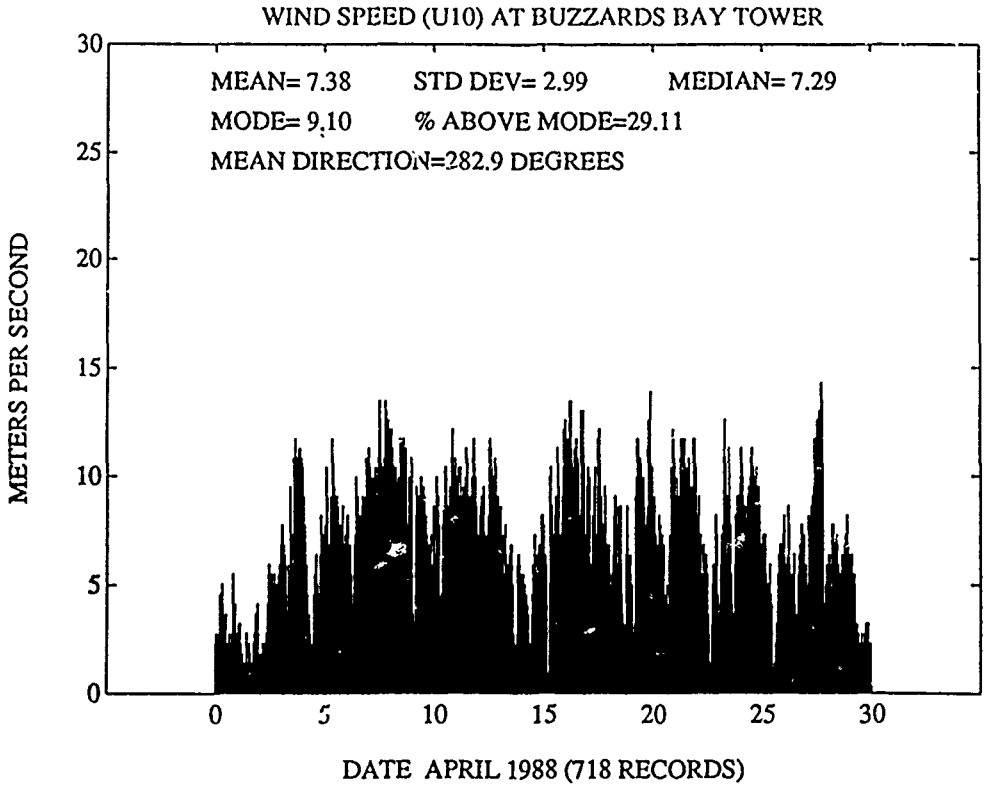


Figure 29: (continued) (c) Wind speed distribution, and (d) wind direction distribution.



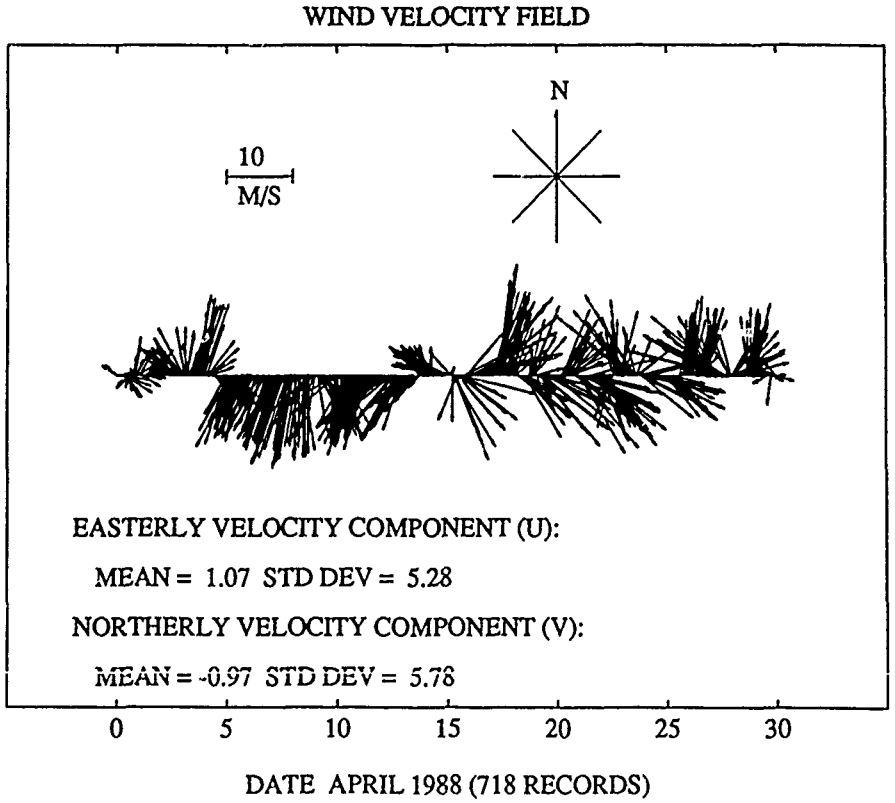
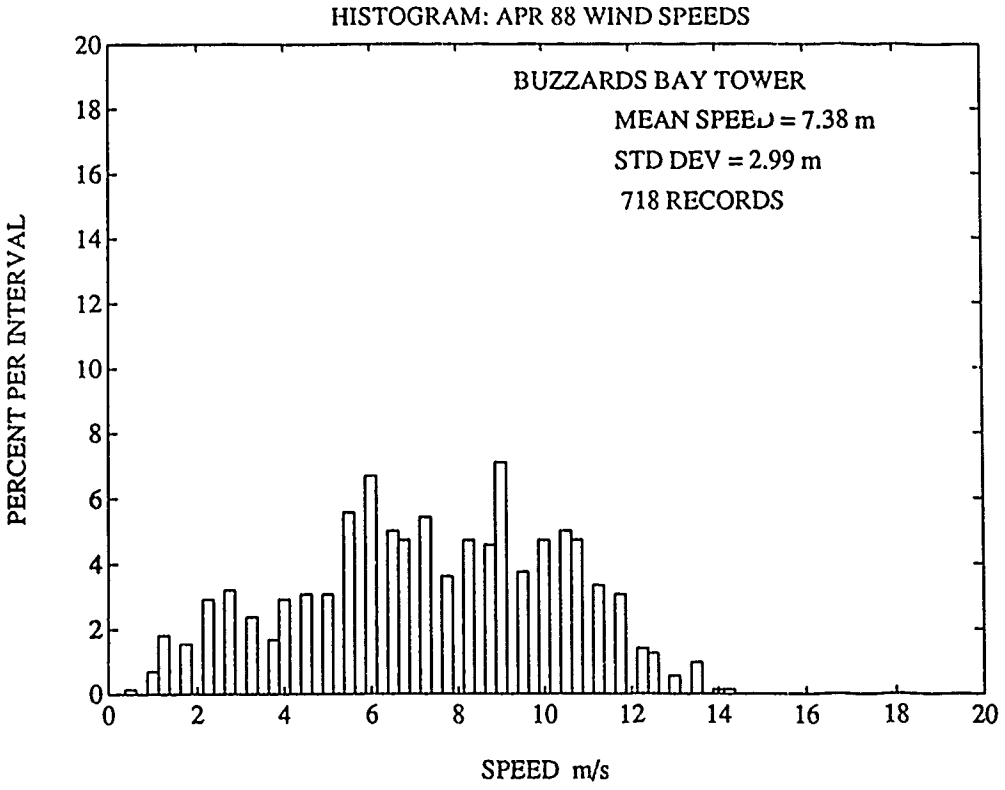


Figure 30: Wind speed and direction at Buzzards Bay Tower, April 1988. (a) Wind speed time series, and (b) wind velocity vector plot.



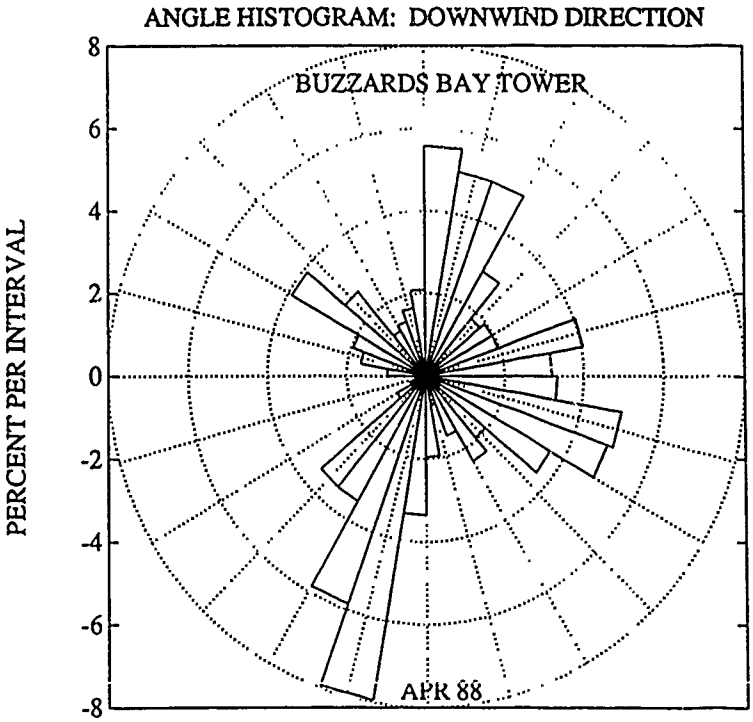
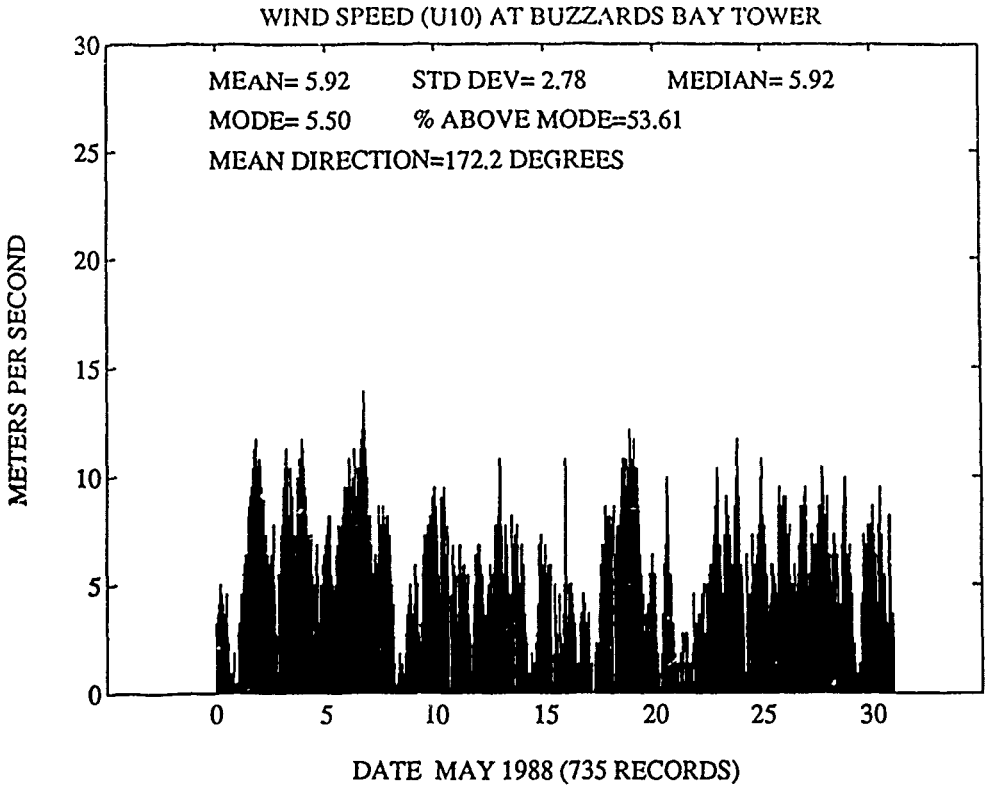


Figure 30: (continued) (c) Wind speed distribution, and (d) wind direction distribution.



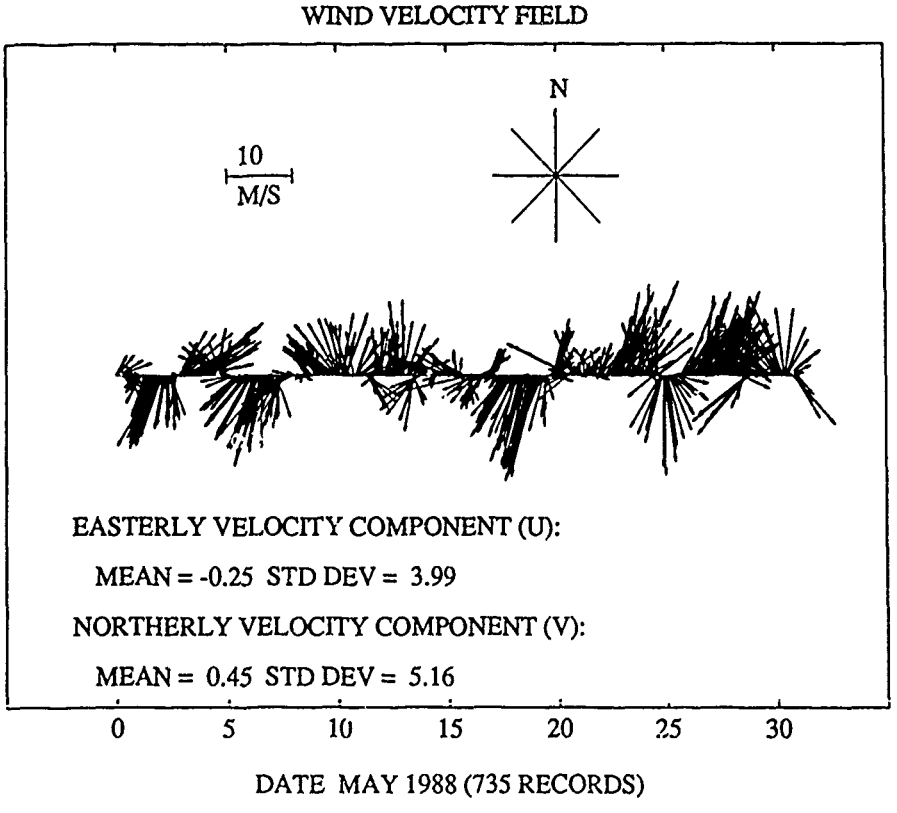
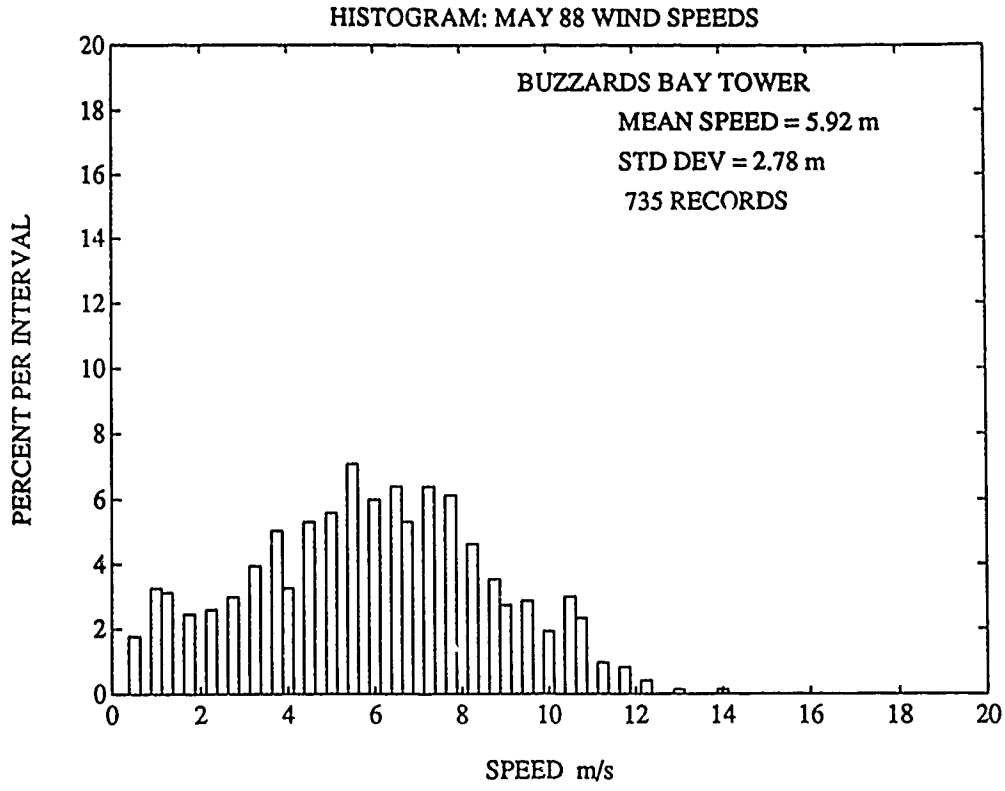


Figure 31: Wind speed and direction at Buzzards Bay Tower, May 1988. (a) Wind speed time series, and (b) wind velocity vector plot.



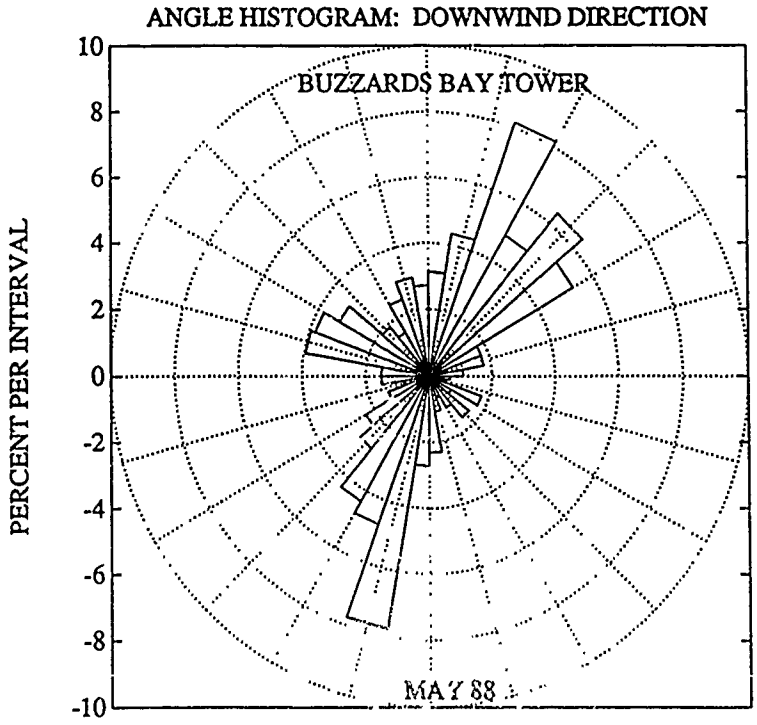
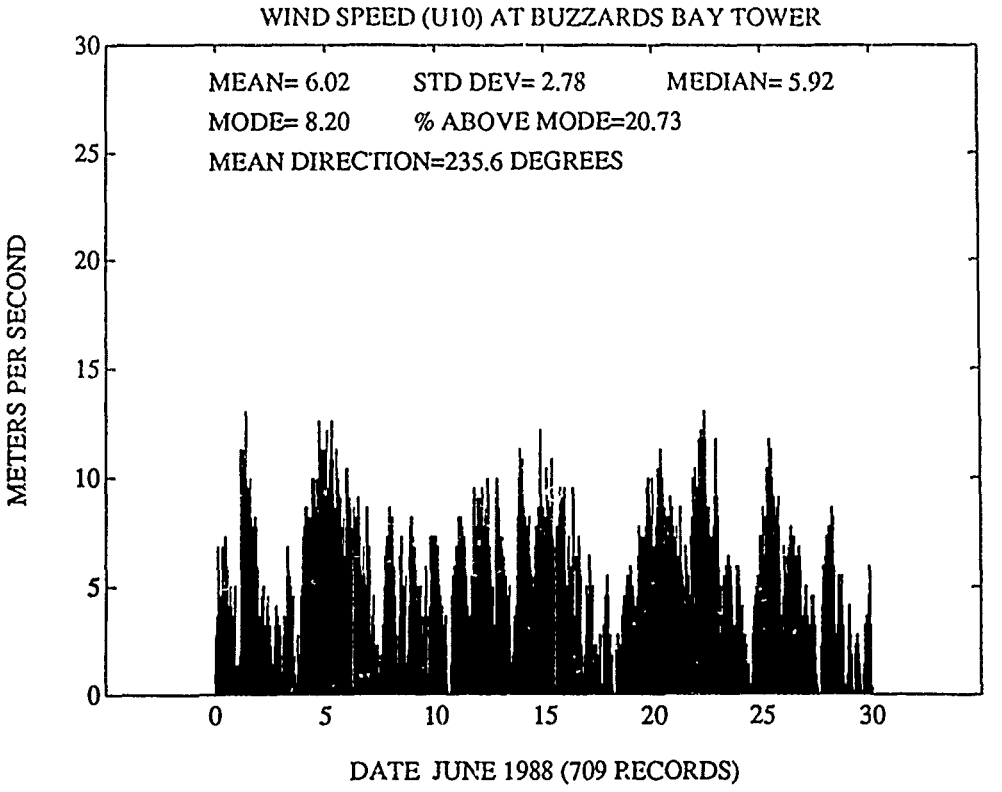


Figure 31: (continued) (c) Wind speed distribution, and (d) wind direction distribution.



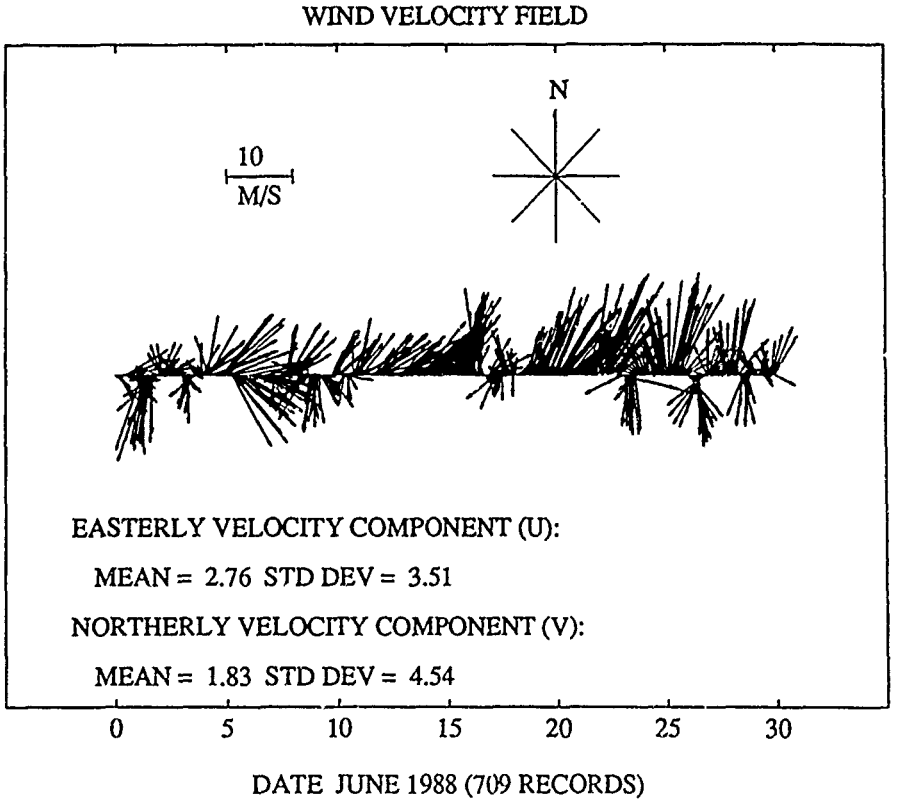
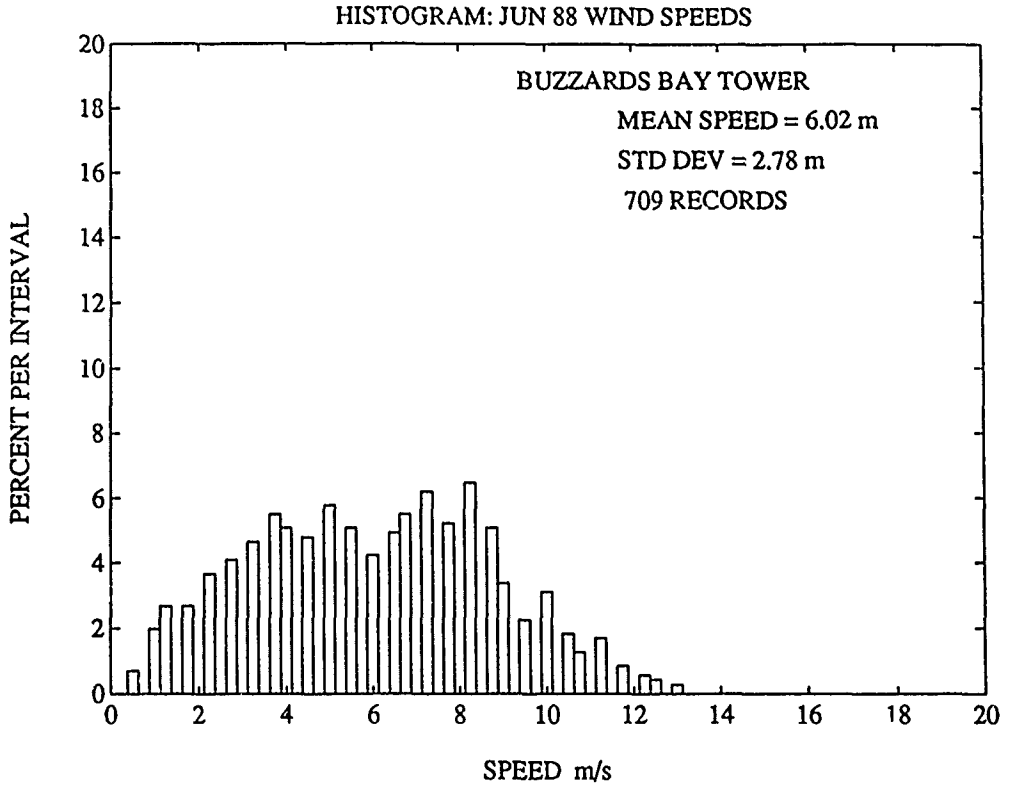


Figure 32: Wind speed and direction at Buzzards Bay Tower, June 1988. (a) Wind speed time series, and (b) wind velocity vector plot.



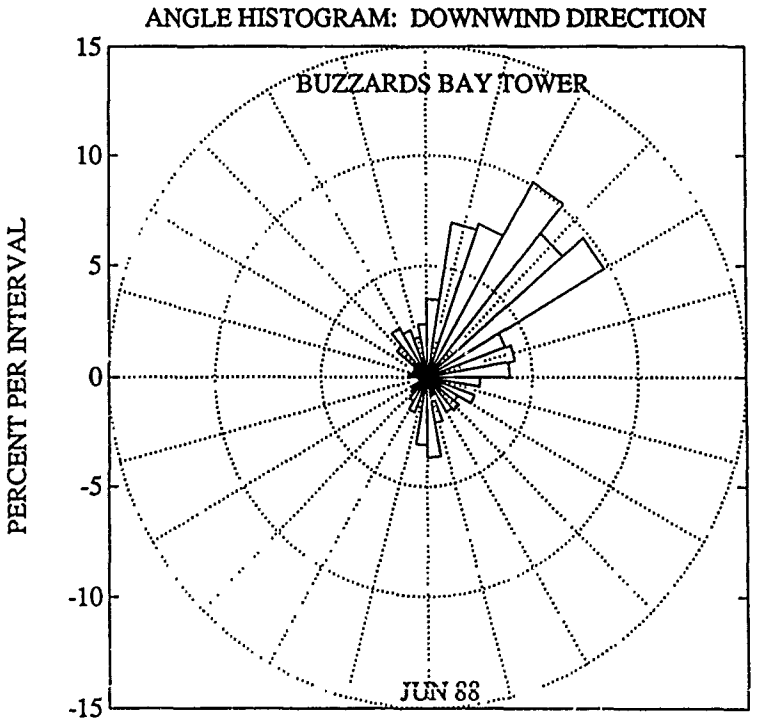
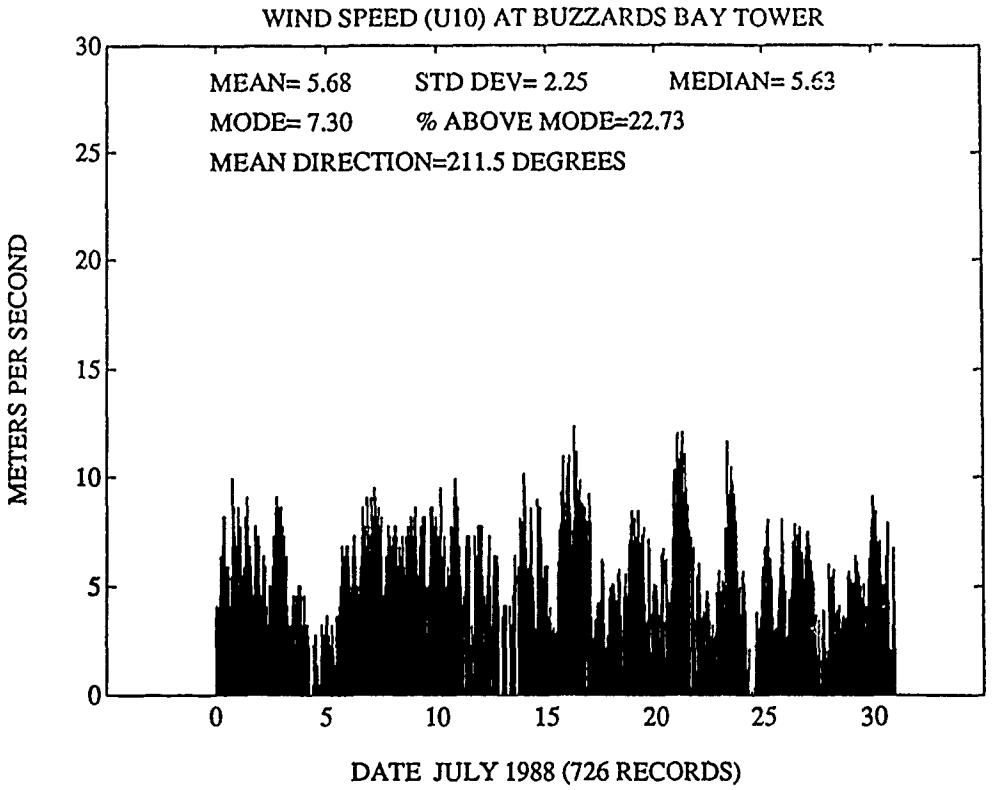


Figure 32: (continued) (c) Wind speed distribution, and (d) wind direction distribution.



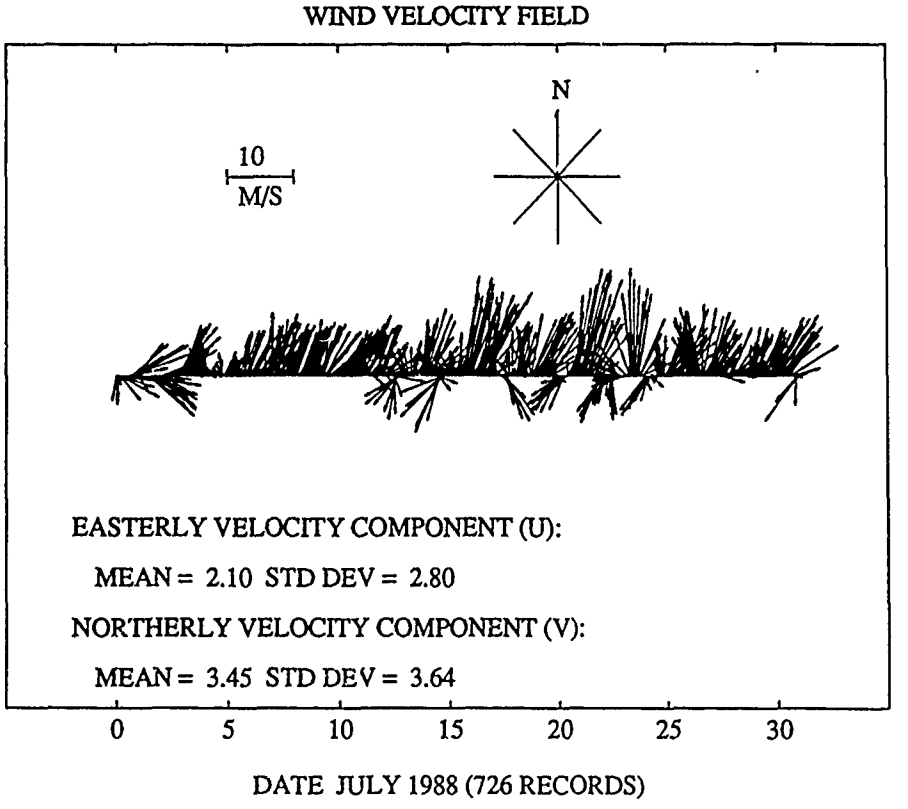
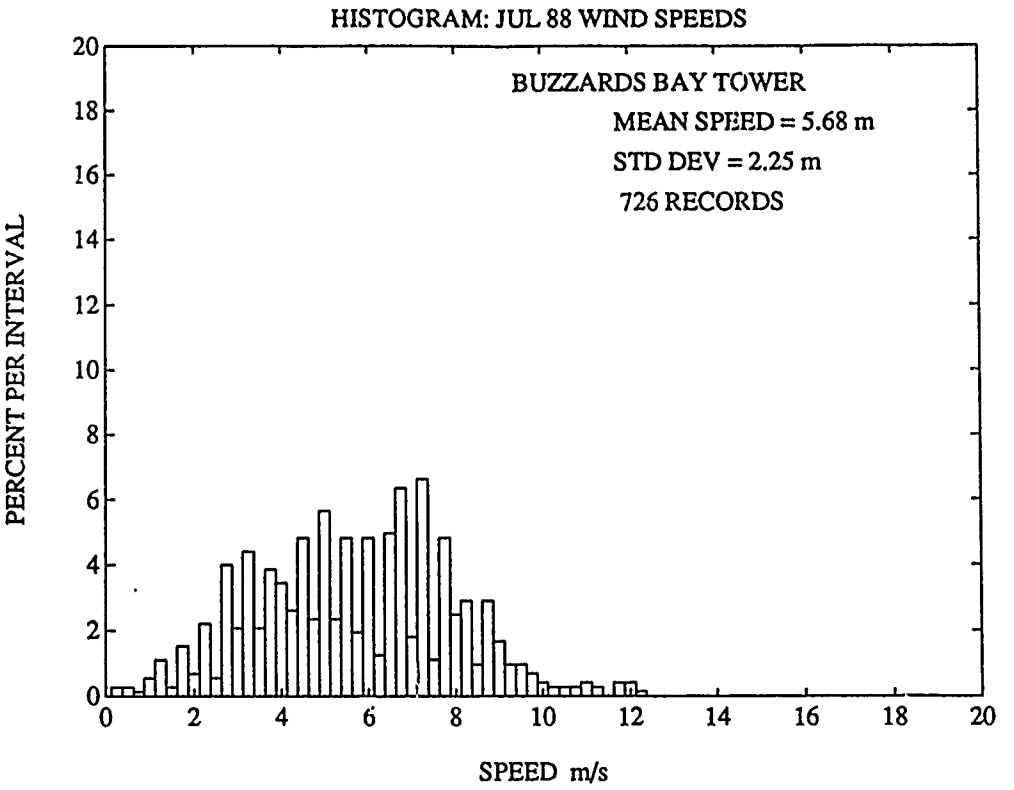


Figure 33: Wind speed and direction at Buzzards Bay Tower, July 1988. (a) Wind speed time series, and (b) wind velocity vector plot.



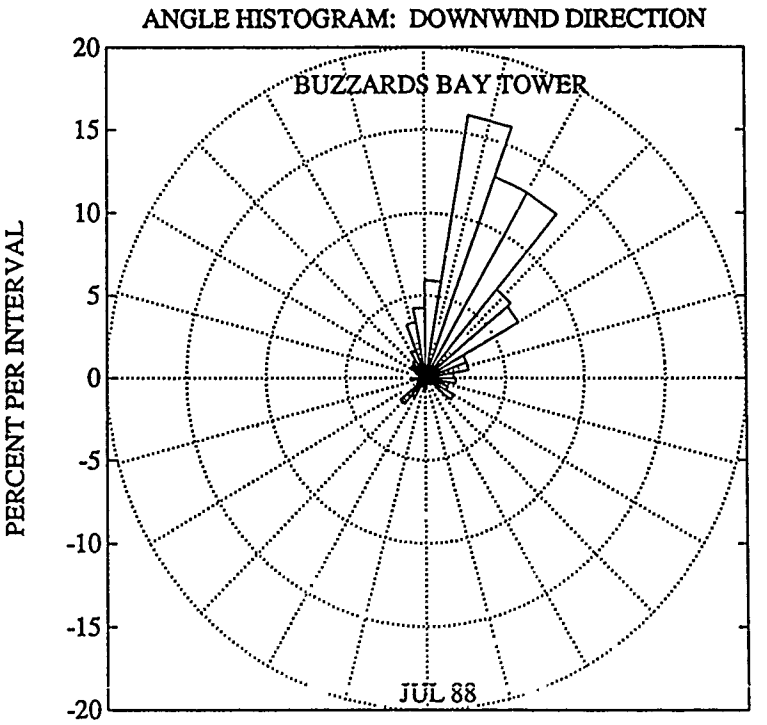
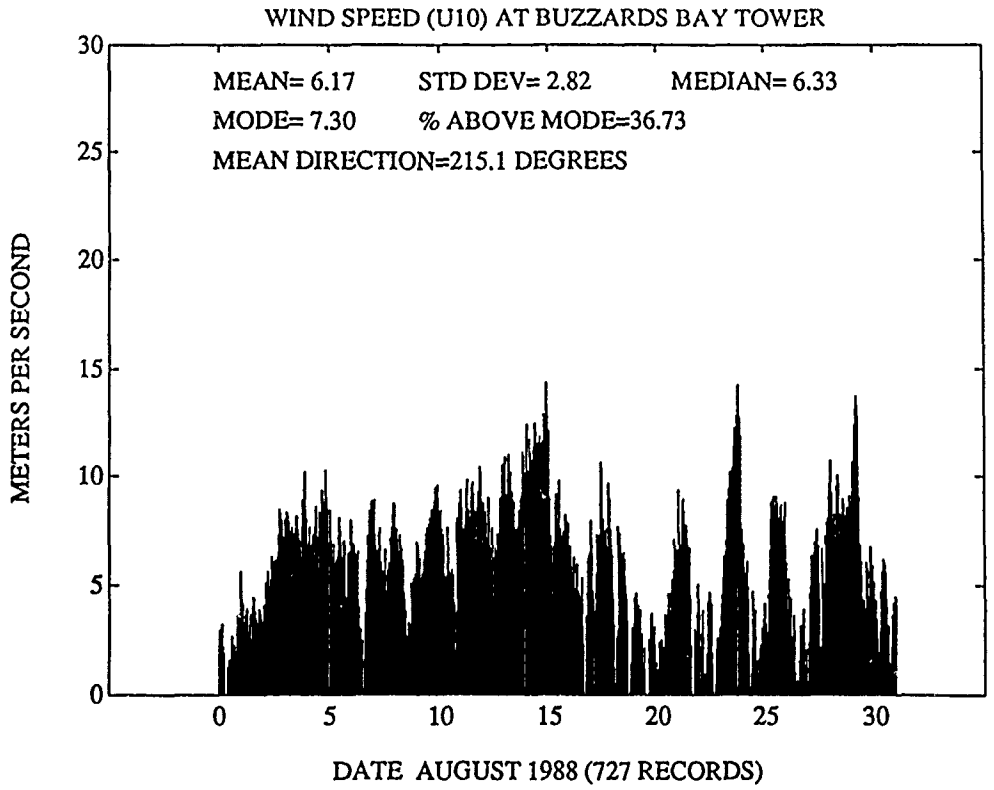


Figure 33: (continued) (c) Wind speed distribution, and (d) wind direction distribution.



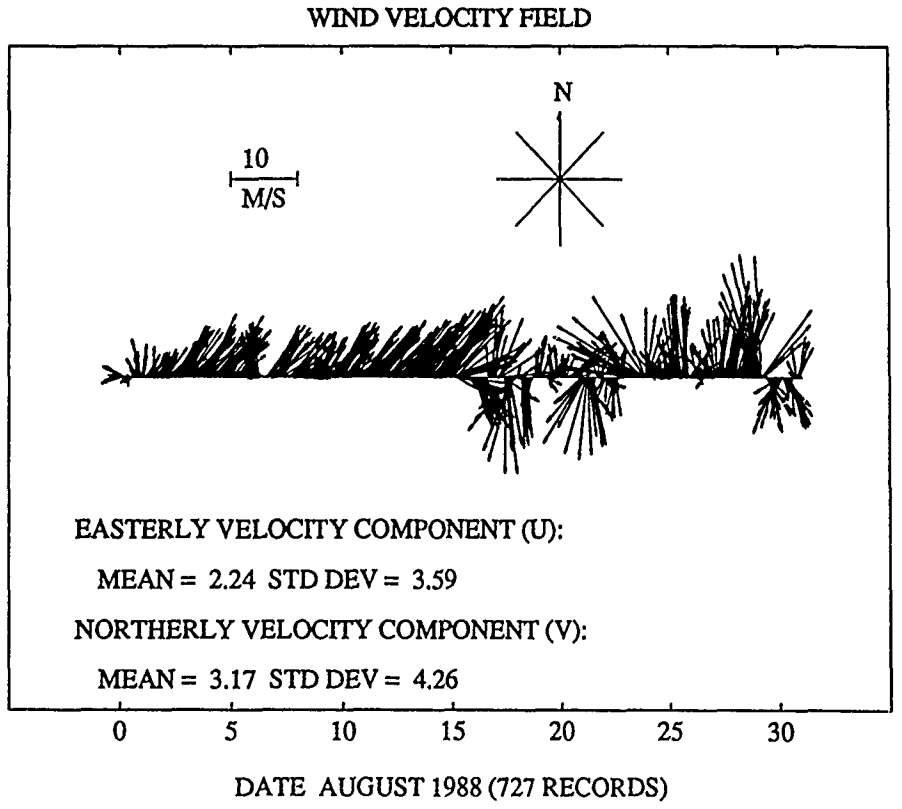
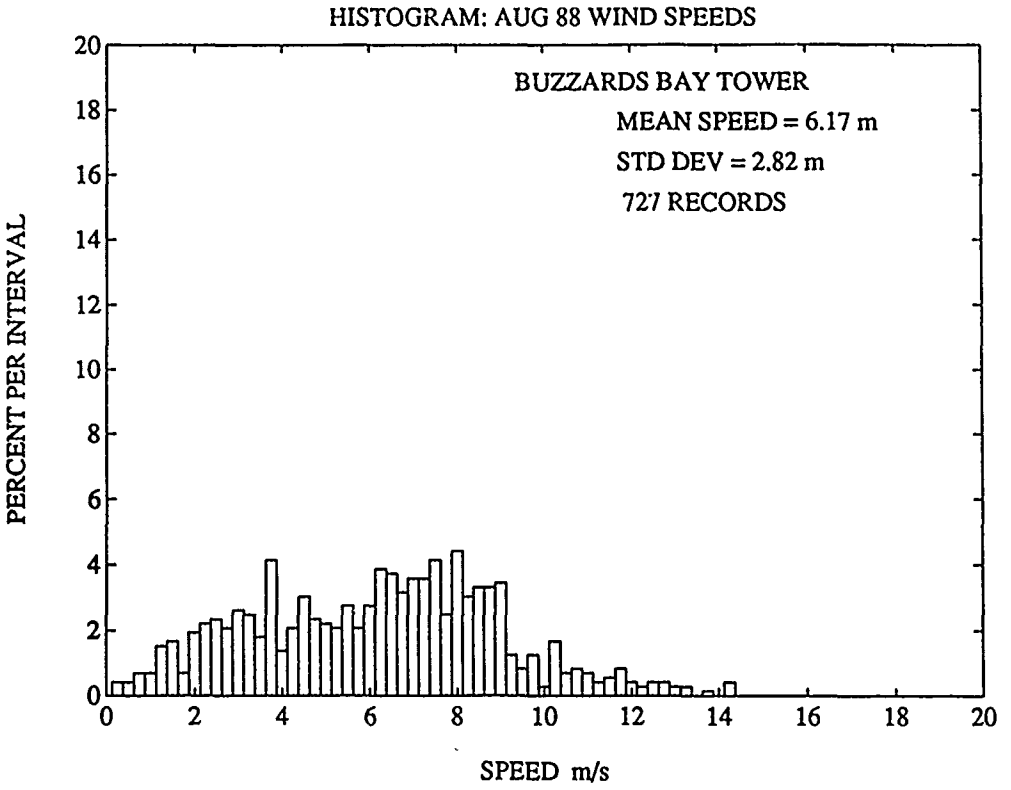


Figure 34: Wind speed and direction at Buzzards Bay Tower, August 1988. (a) Wind speed time series, and (b) wind velocity vector plot.



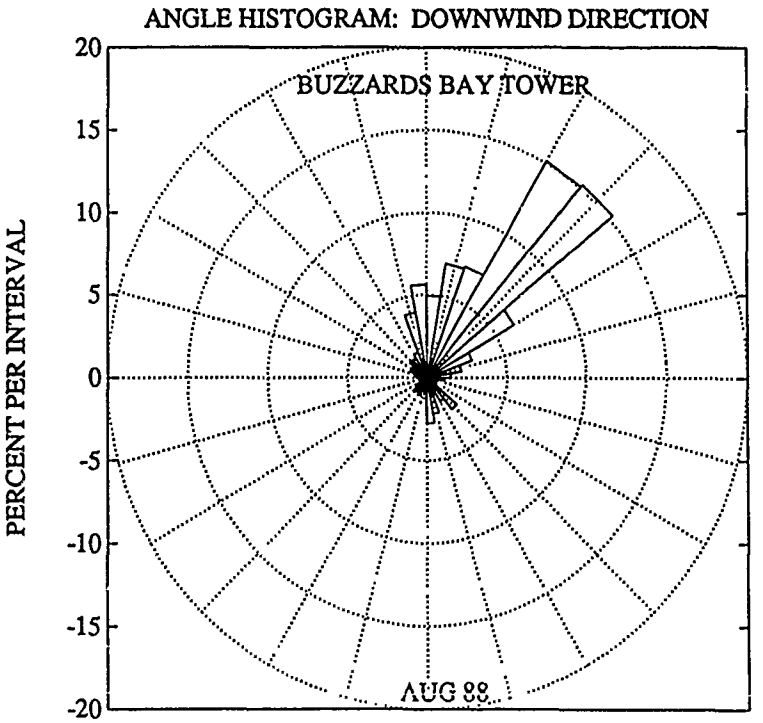
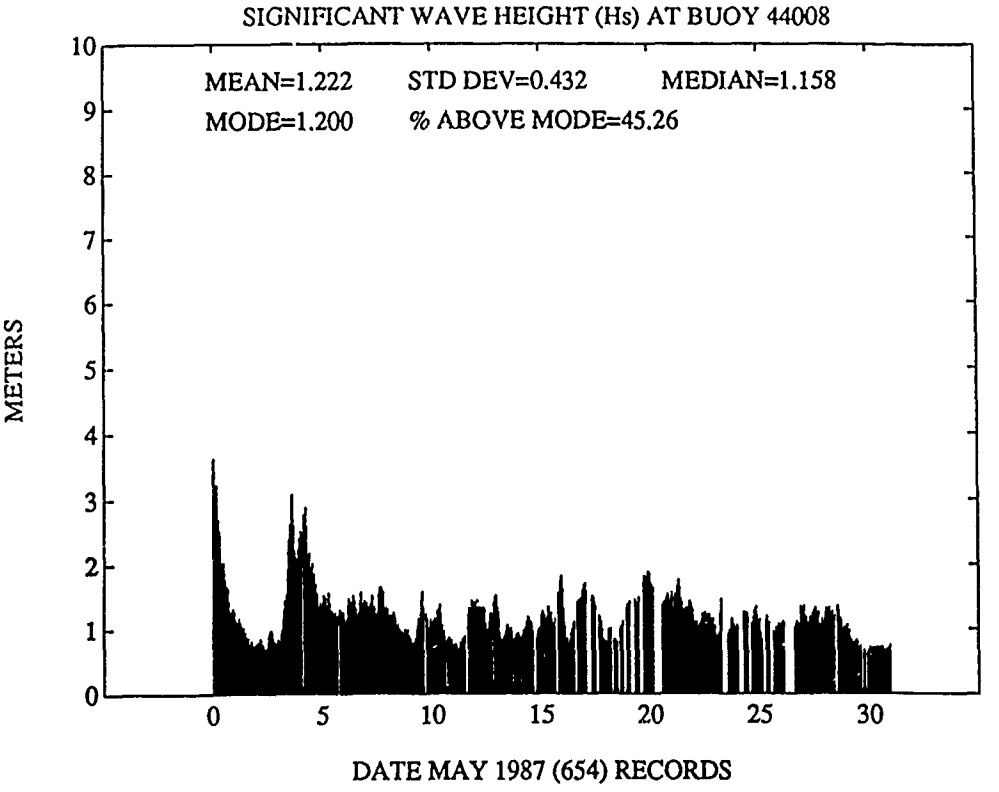


Figure 34: (continued) (c) Wind speed distribution, and (d) wind direction distribution.



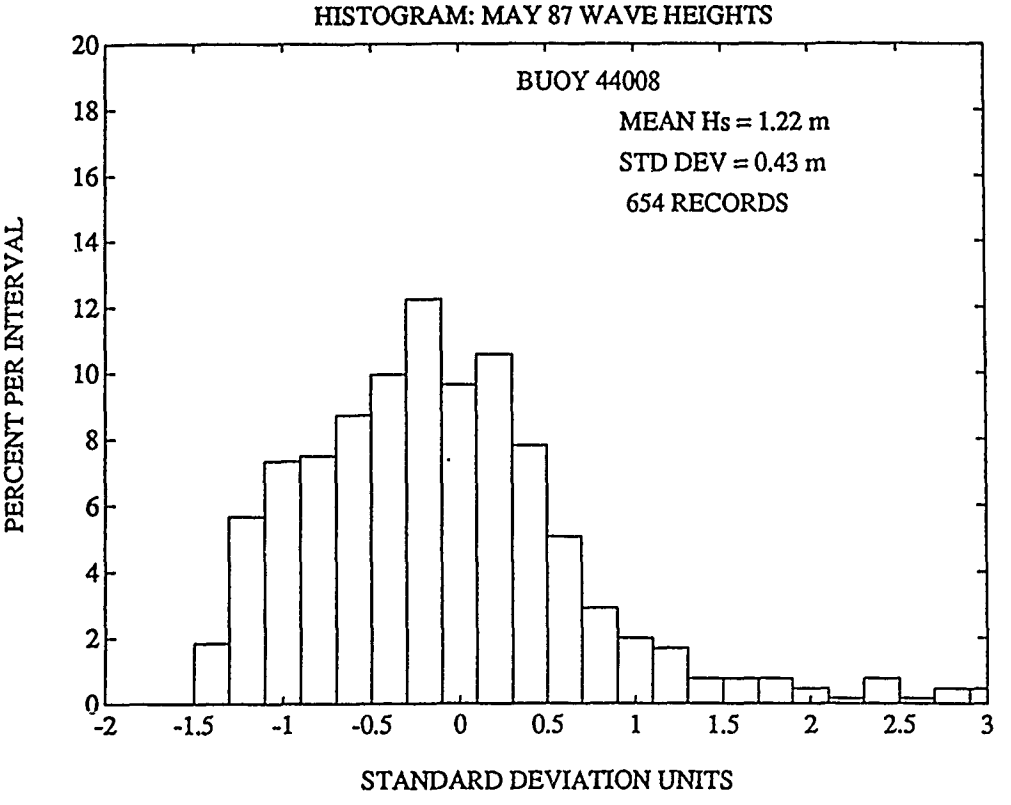
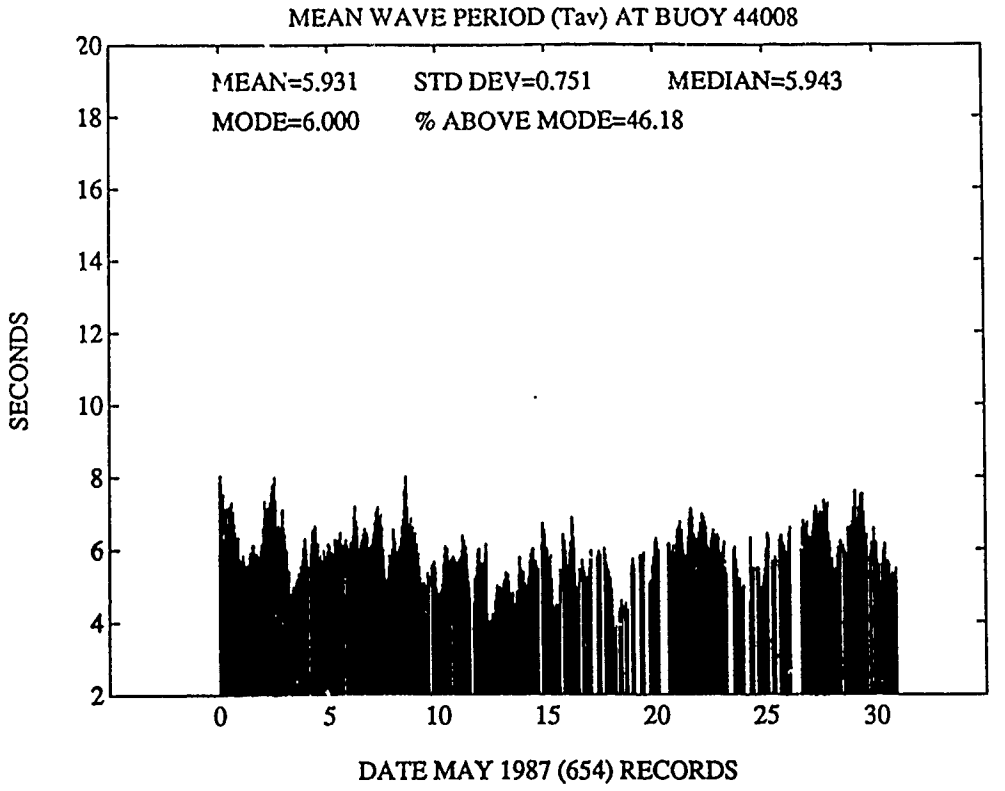


Figure 35: Wave height and period at Buoy 44008, May 1987. (a) Significant wave height time series, and (b) distribution.



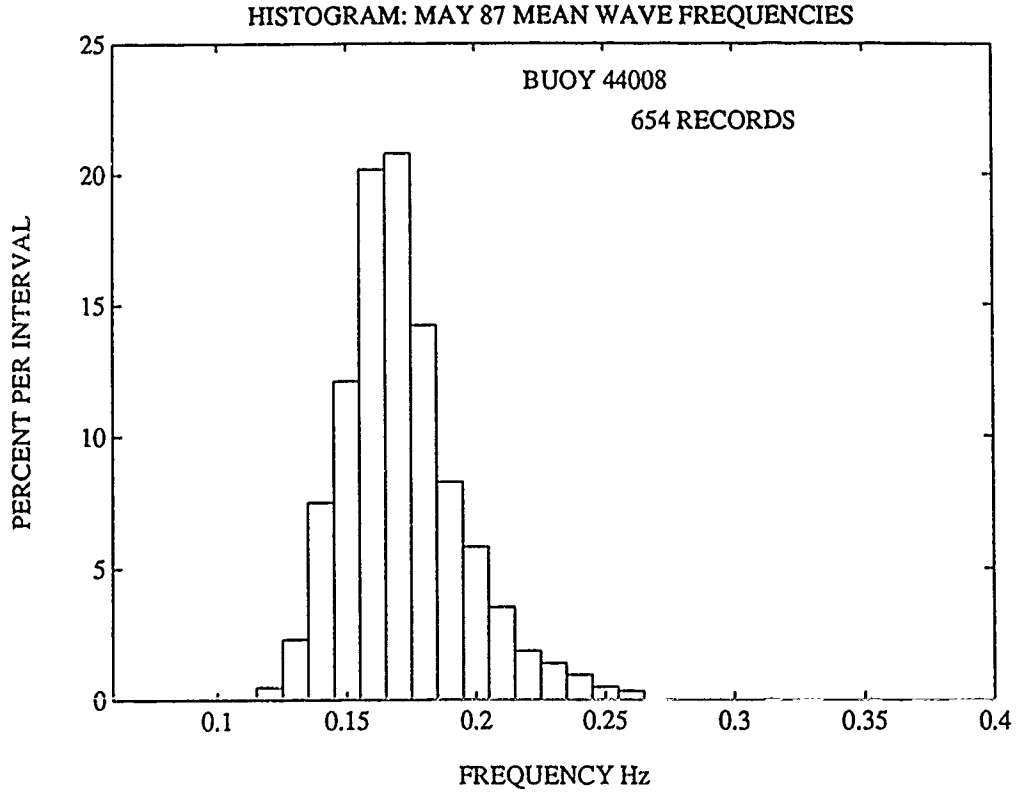
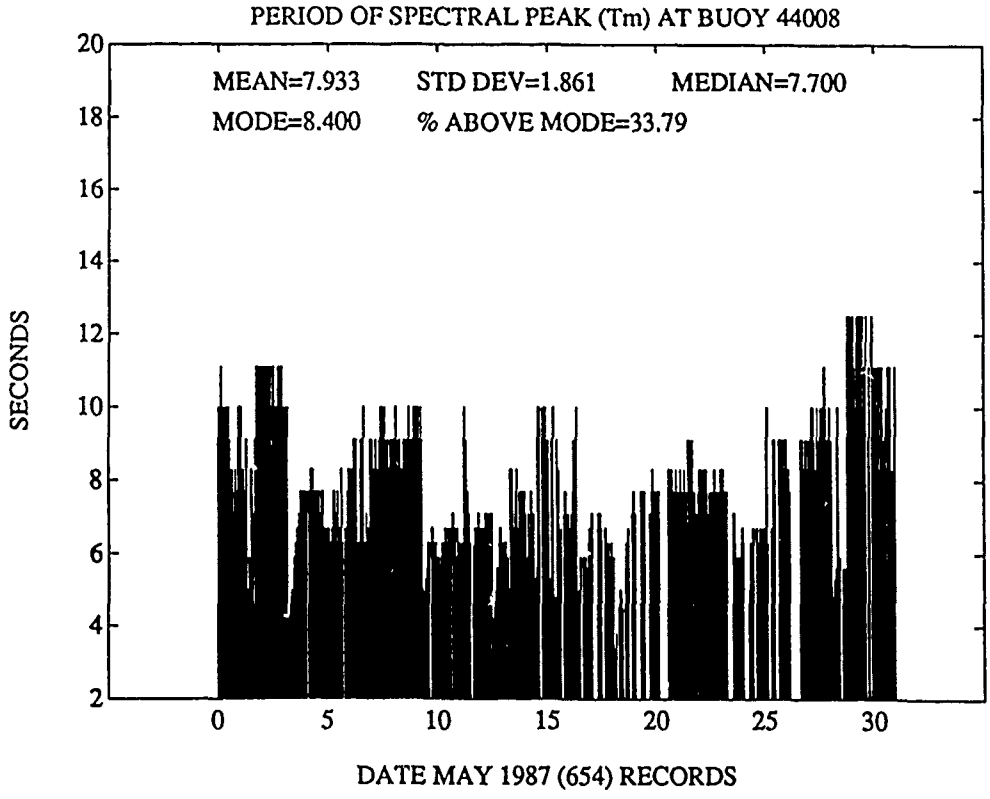


Figure 35: (continued) (c) Mean wave period time series, and (d) mean wave frequency distribution.



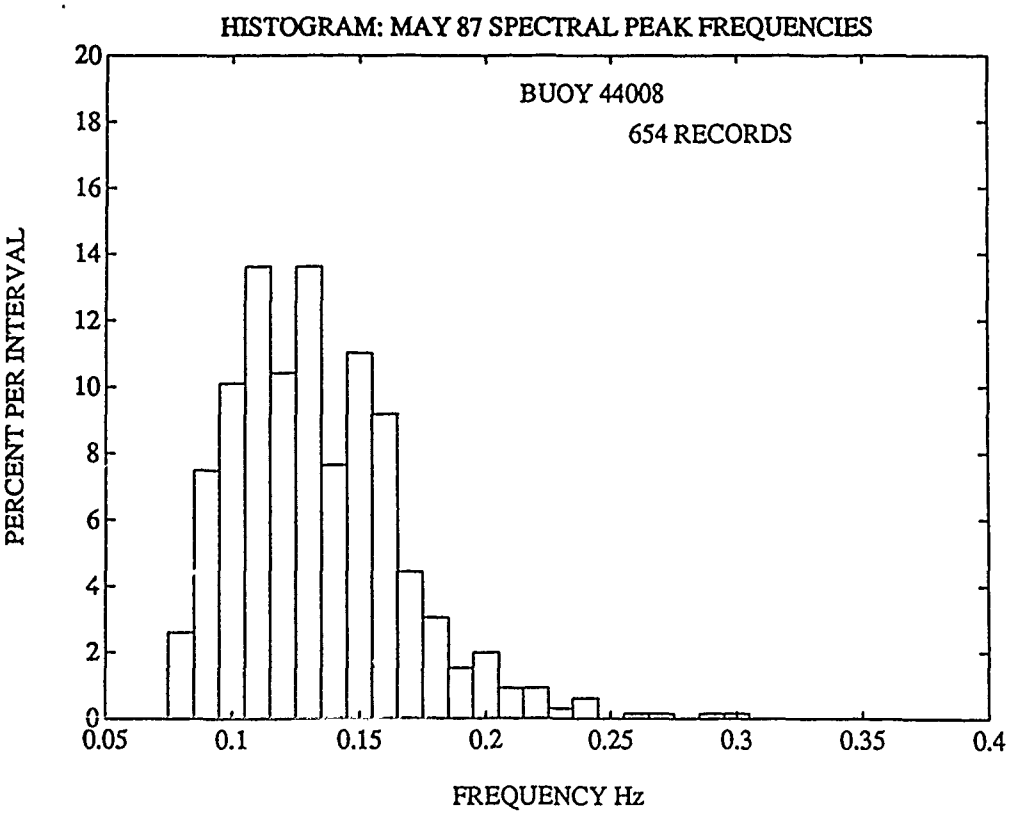


Figure 35: (continued) (e) Spectral peak period time series, and (f) spectral peak frequency distribution.

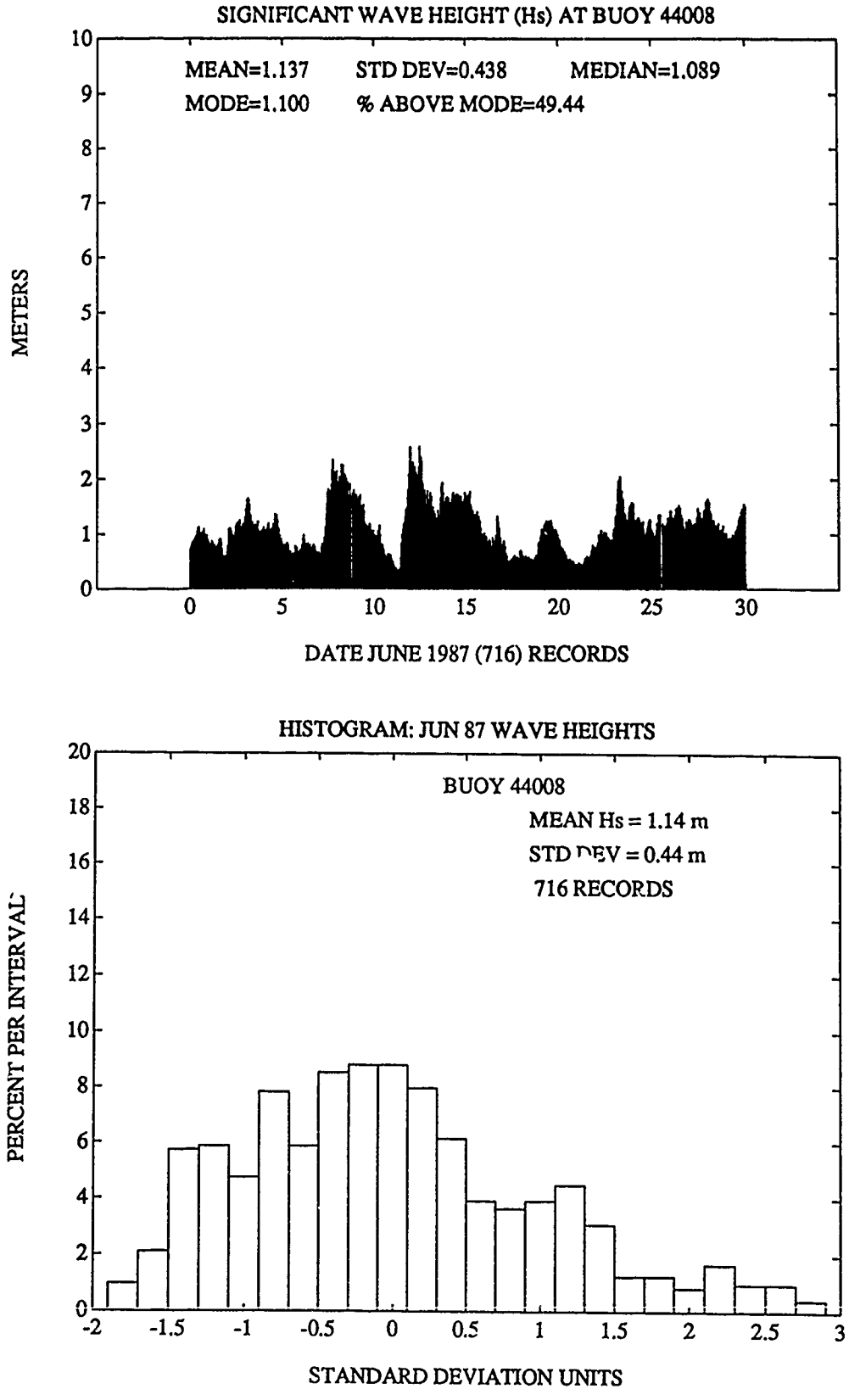
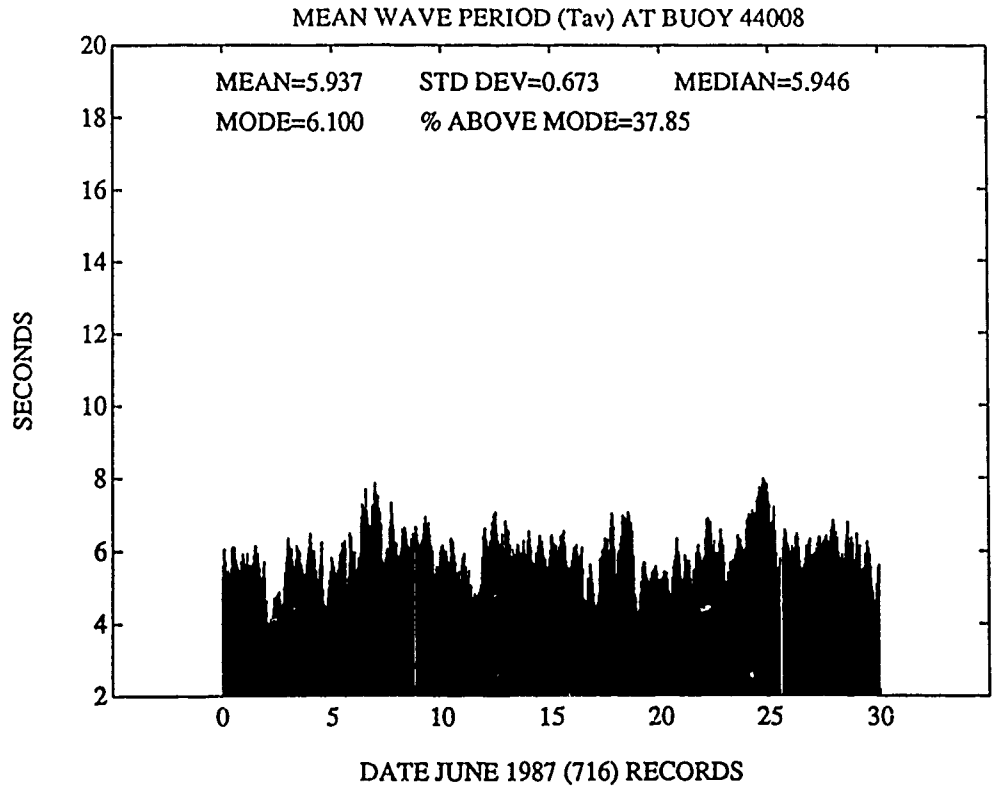


Figure 36: Wave height and period at Buoy 44008, June 1987. (a) Significant wave height time series, and (b) distribution.



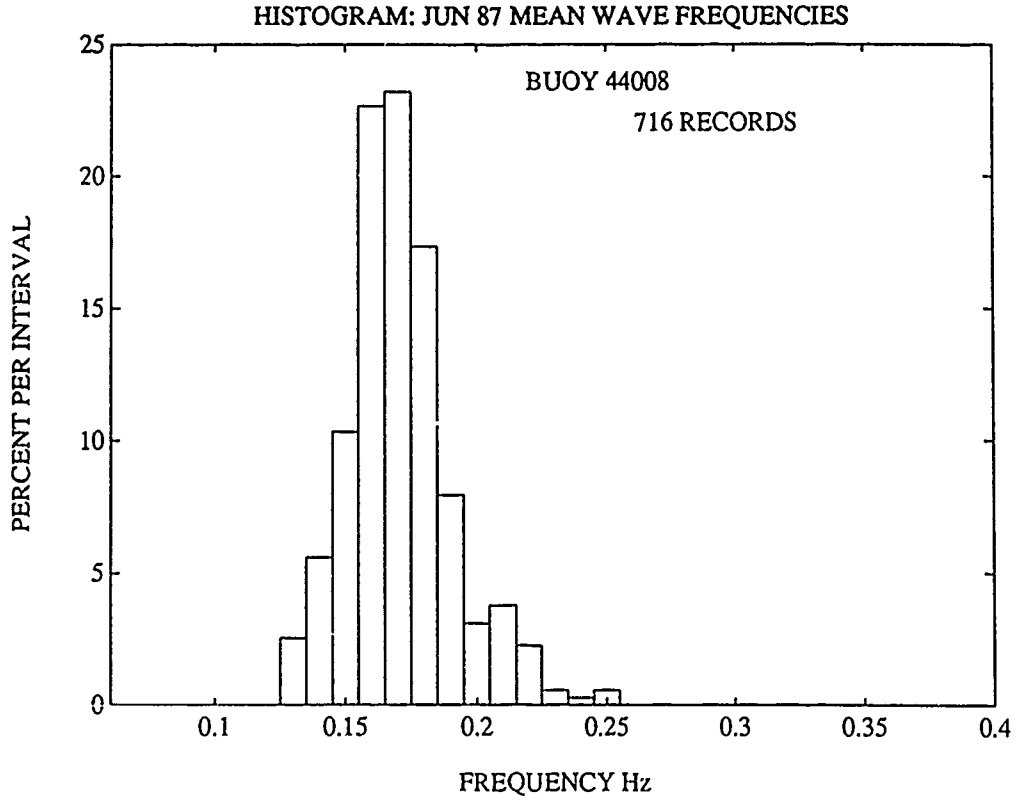
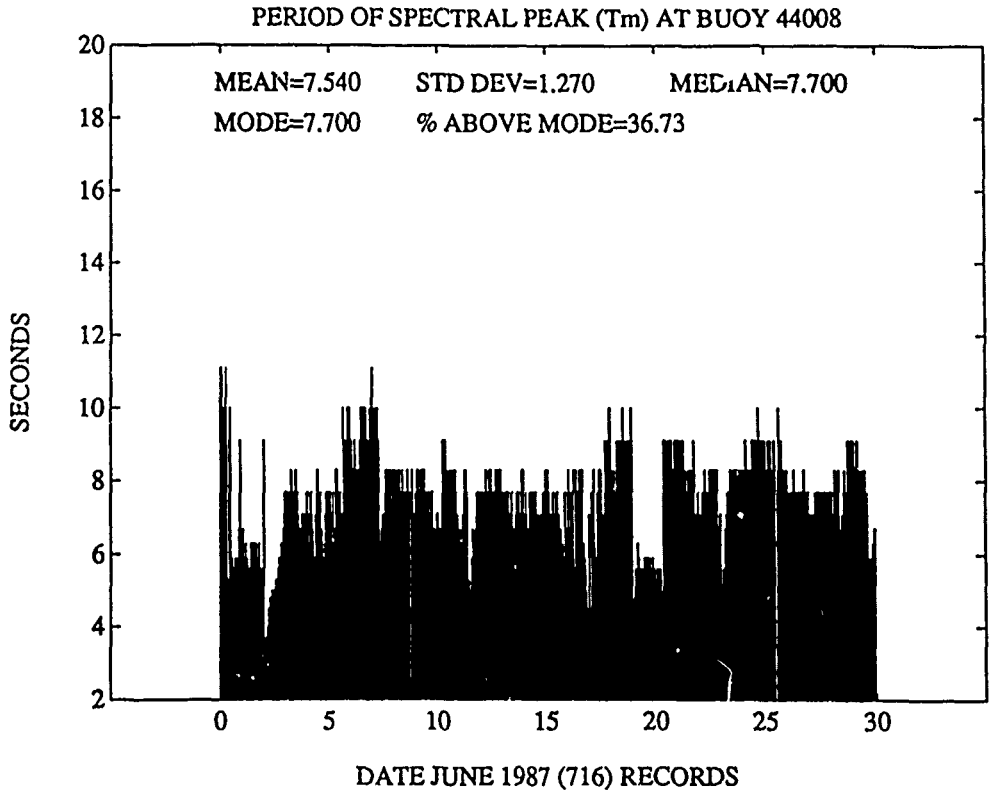


Figure 36: (continued) (c) Mean wave period time series, and (d) mean wave frequency distribution.



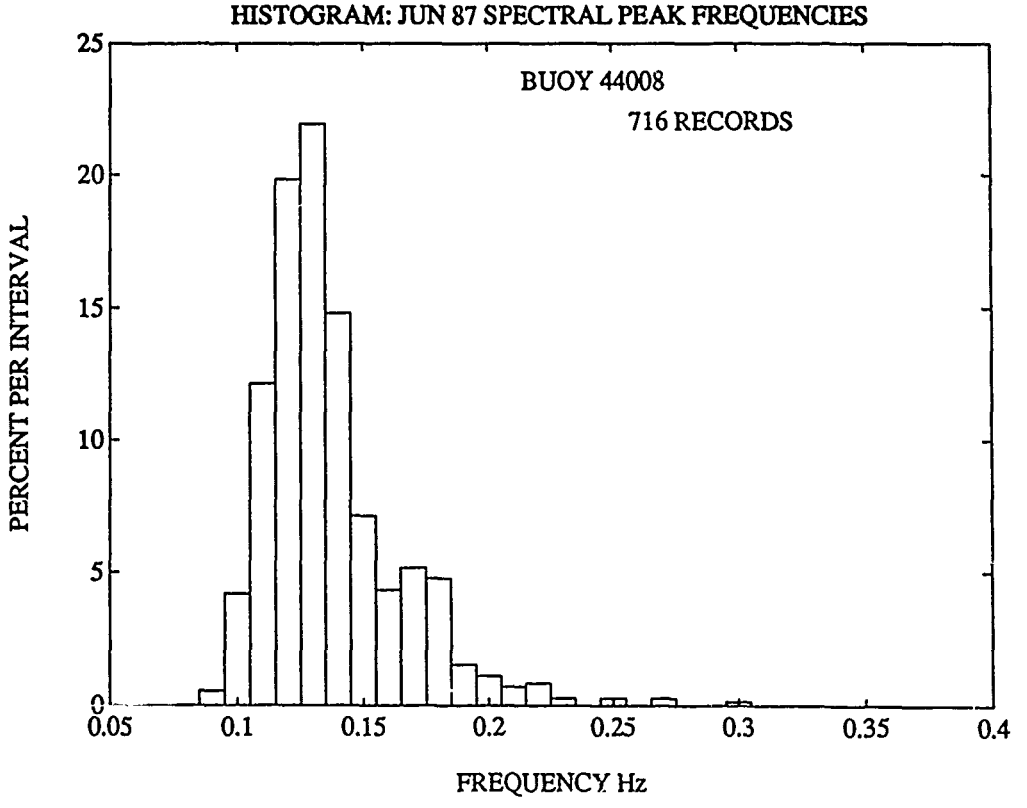
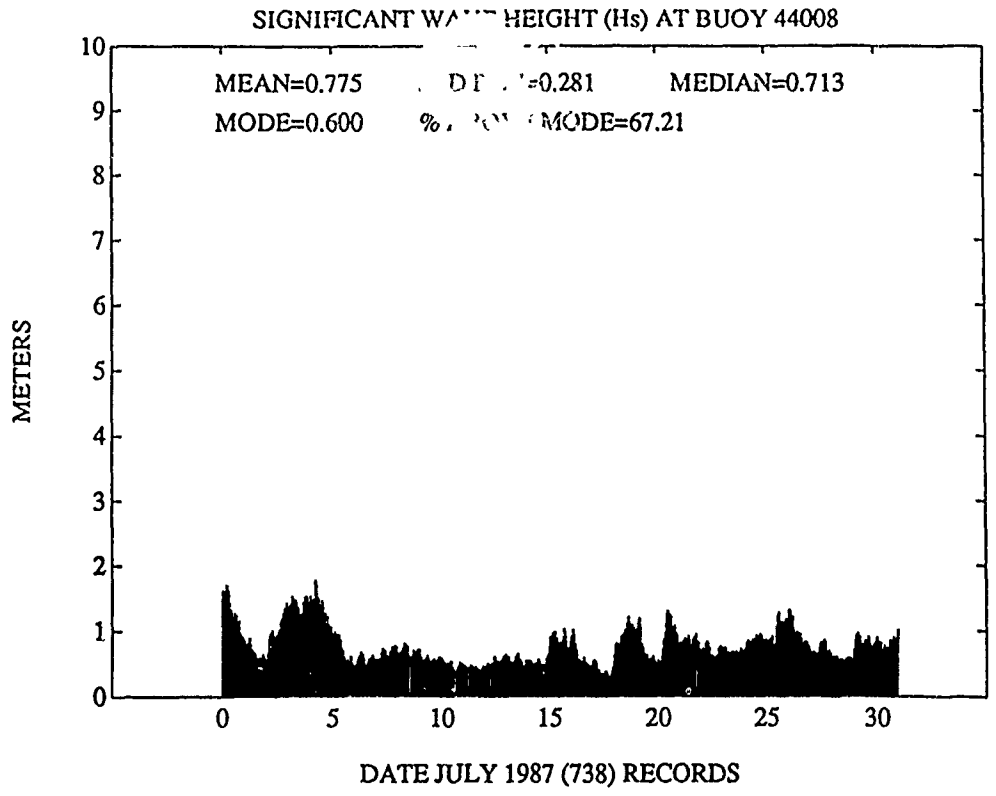


Figure 36: (continued) (e) Spectral peak period time series, and (f) spectral peak frequency distribution.



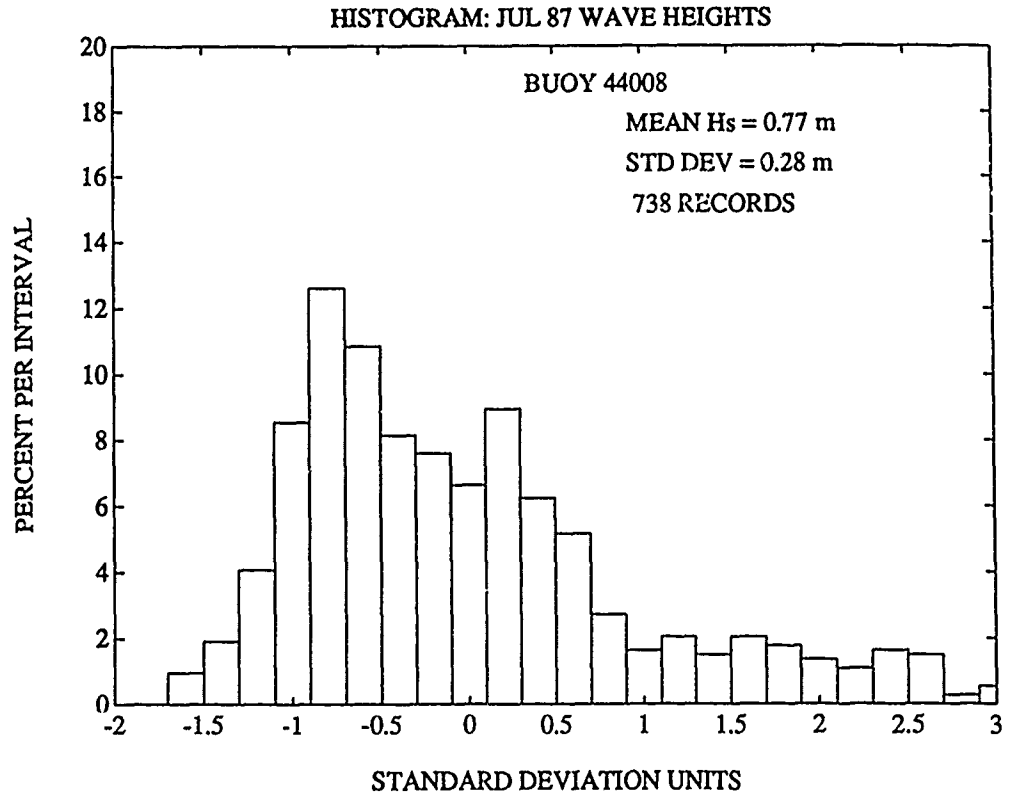
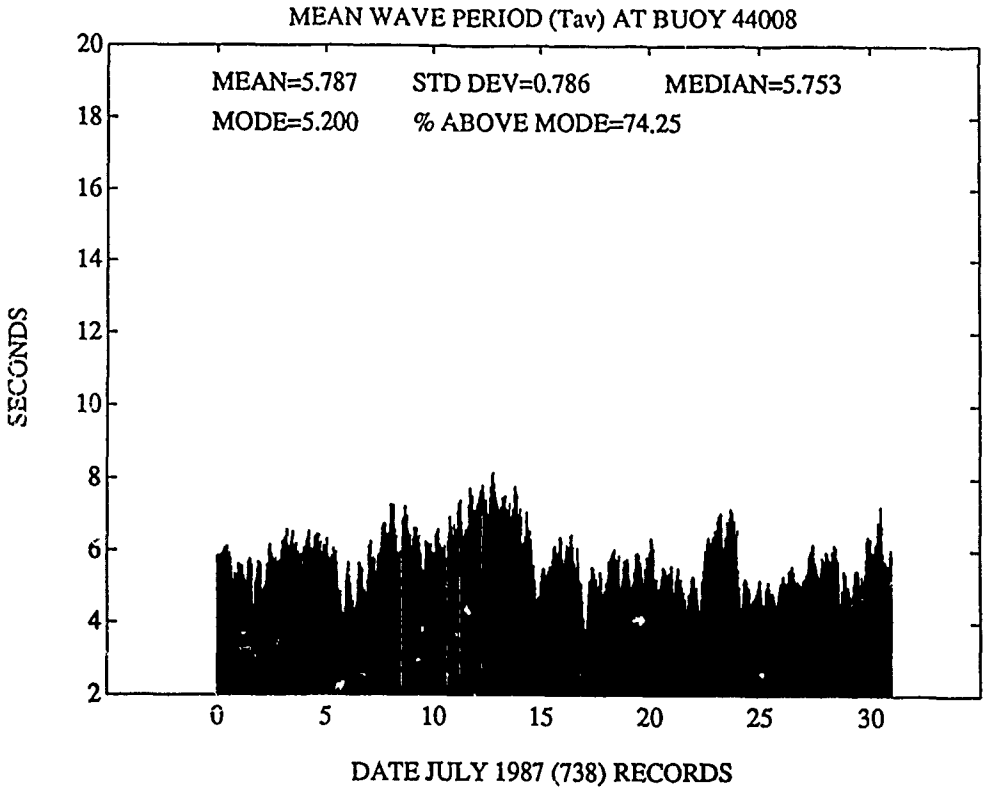


Figure 37: Wave height and period at Buoy 44008, July 1987. (a) Significant wave height time series, and (b) distribution.



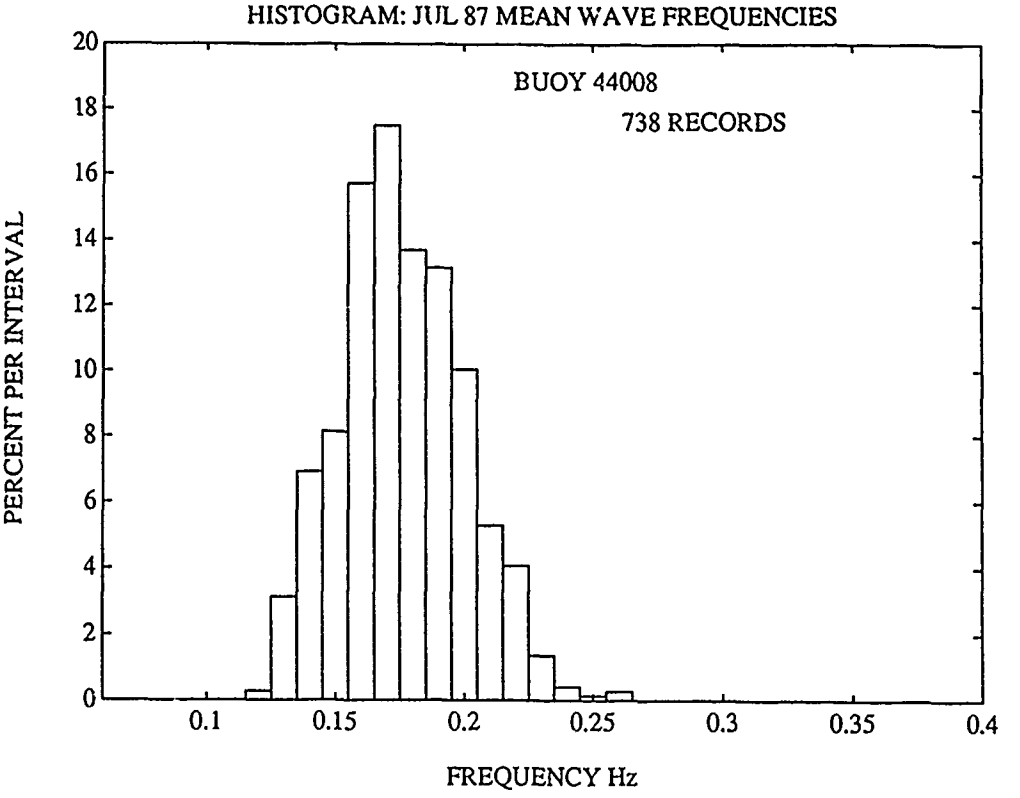
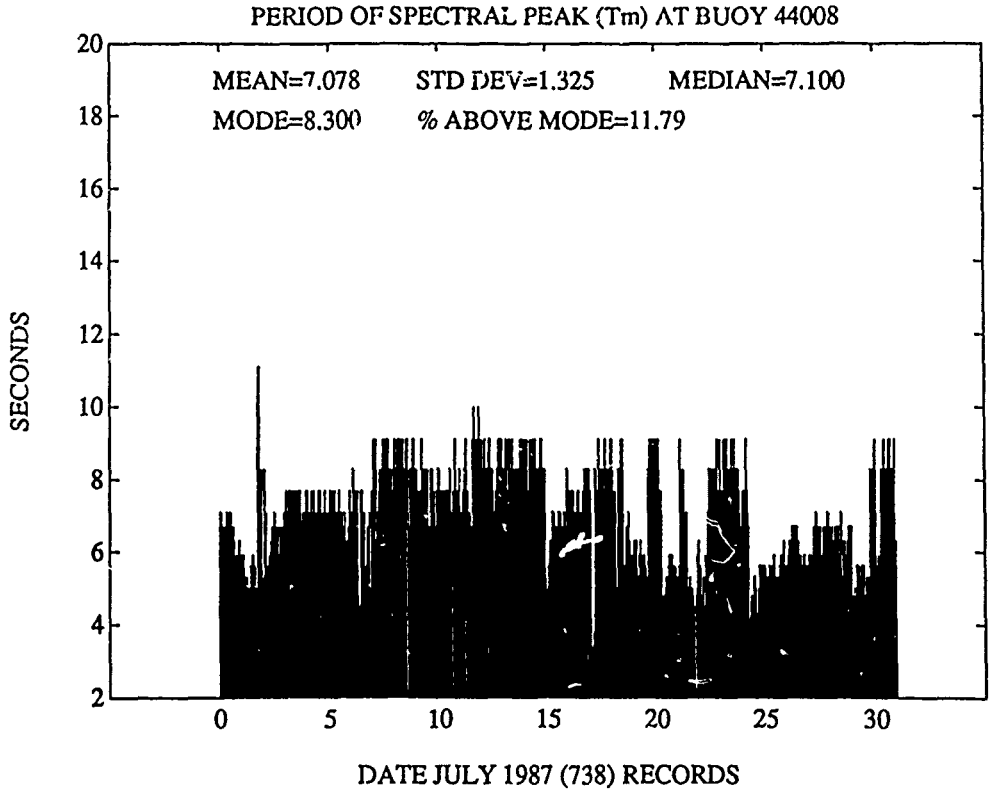


Figure 37: (continued) (c) Mean wave period time series, and (d) mean wave frequency distribution.



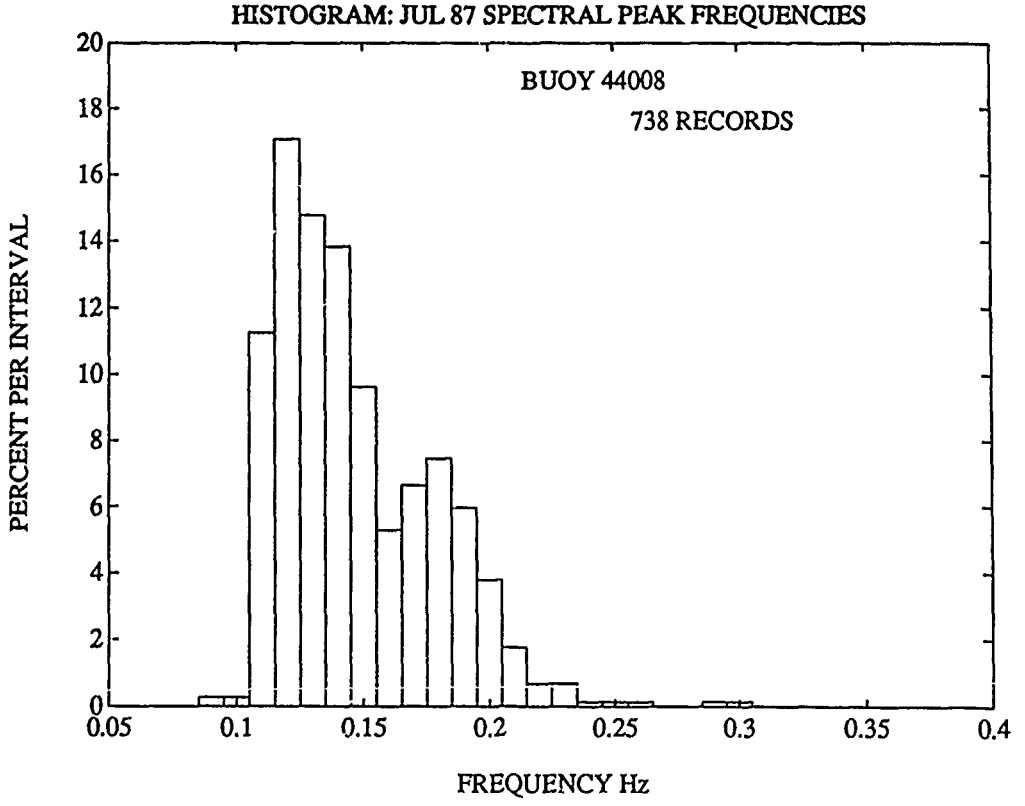


Figure 37: (continued) (e) Spectral peak period time series, and (f) spectral peak frequency distribution.

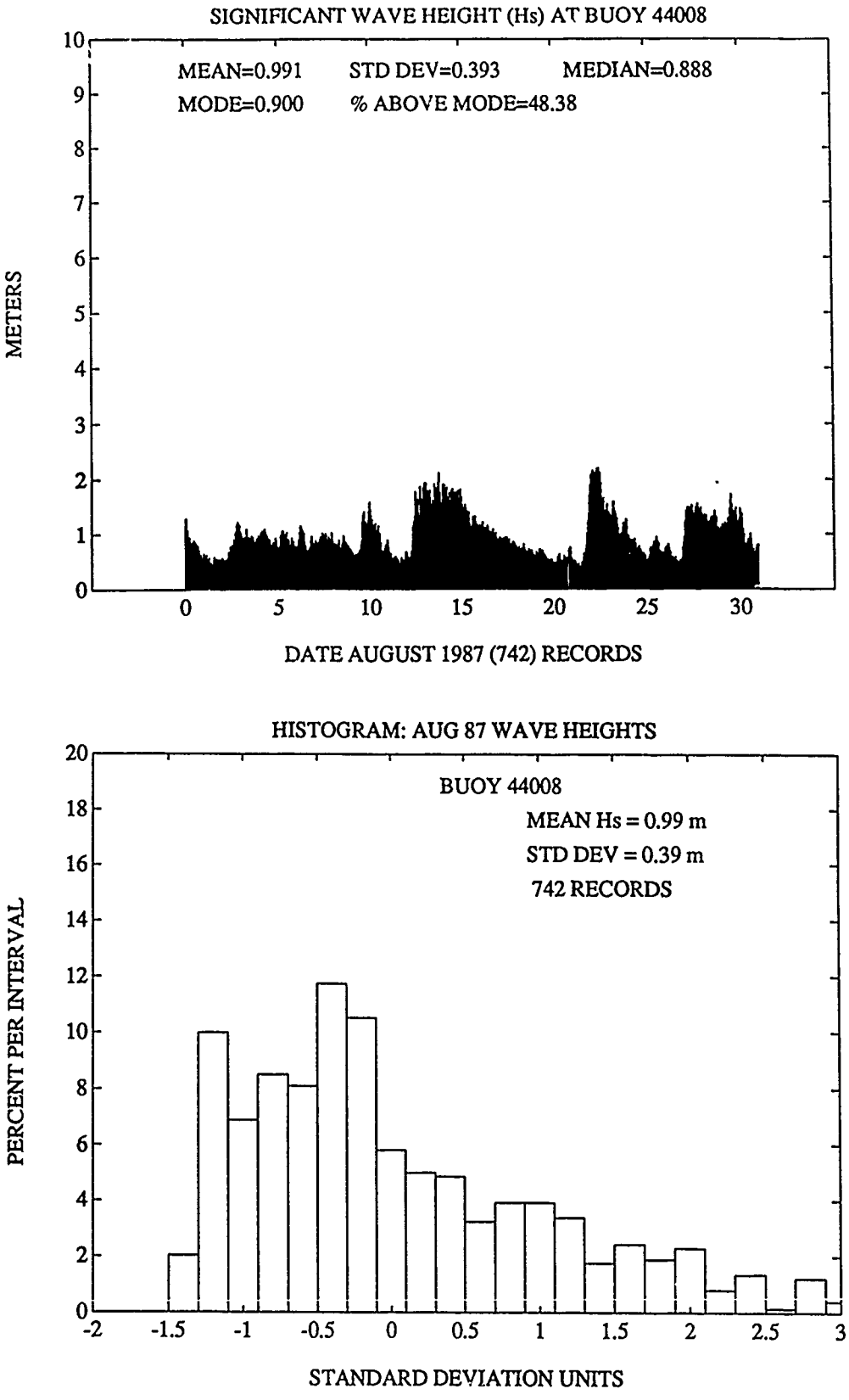
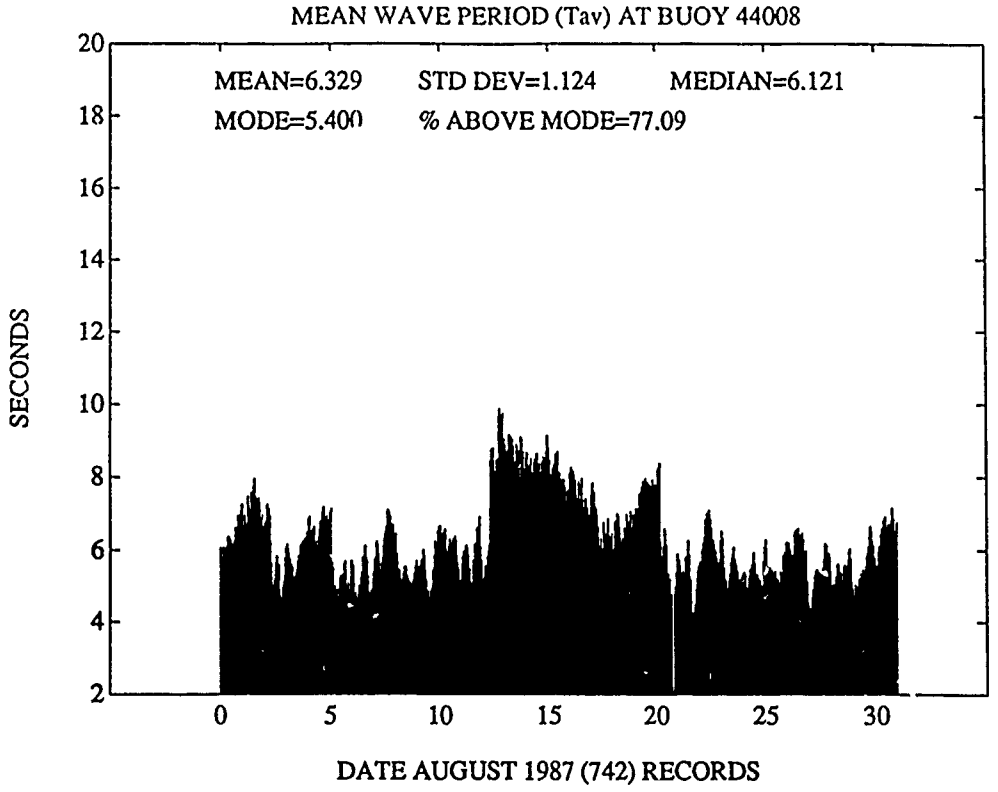


Figure 38: Wave height and period at Buoy 44008, August 1987. (a) Significant wave height time series, and (b) distribution.



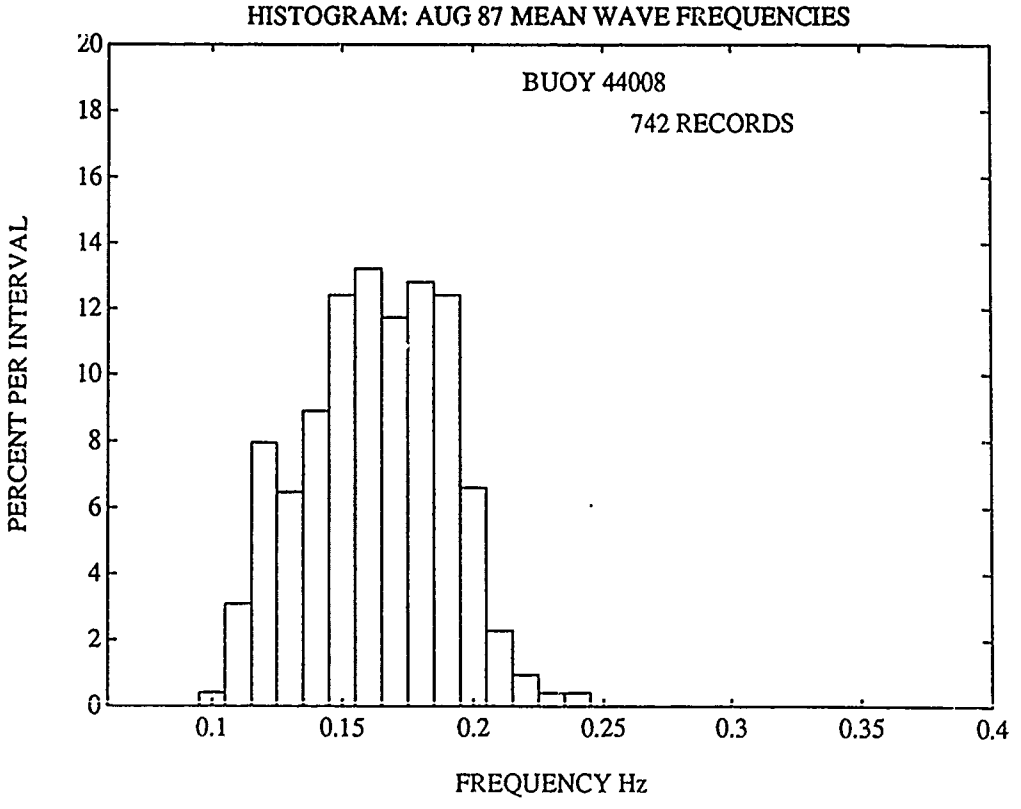
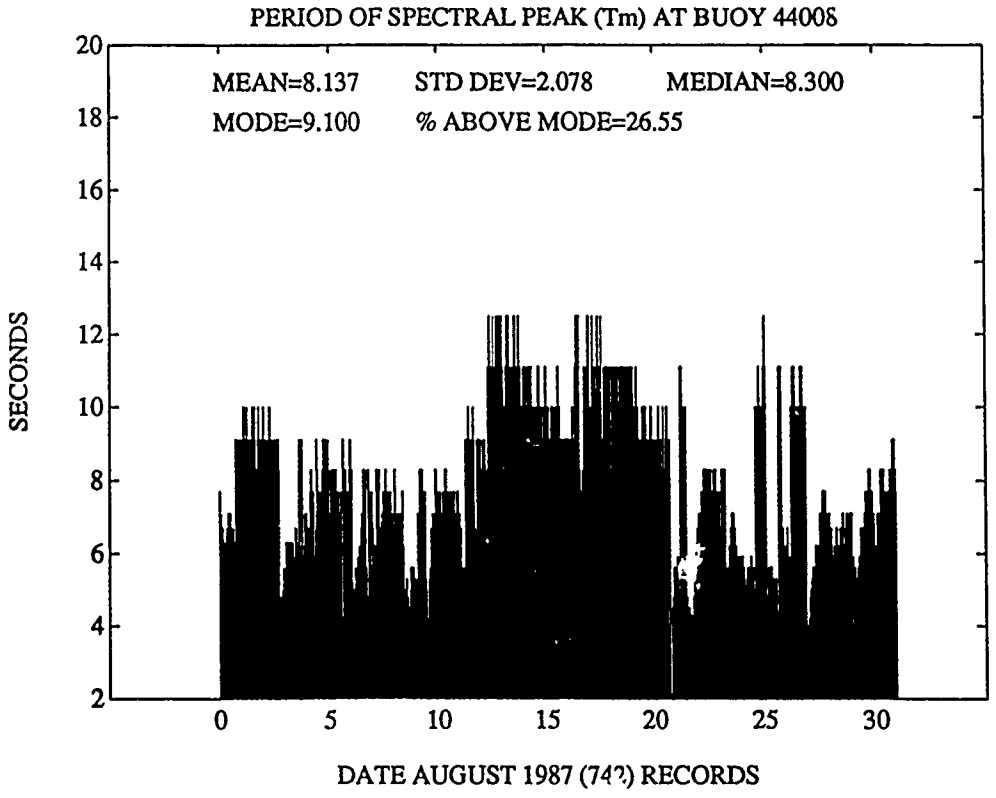


Figure 38: (continued) (c) Mean wave period time series, and (d) mean wave frequency distribution.



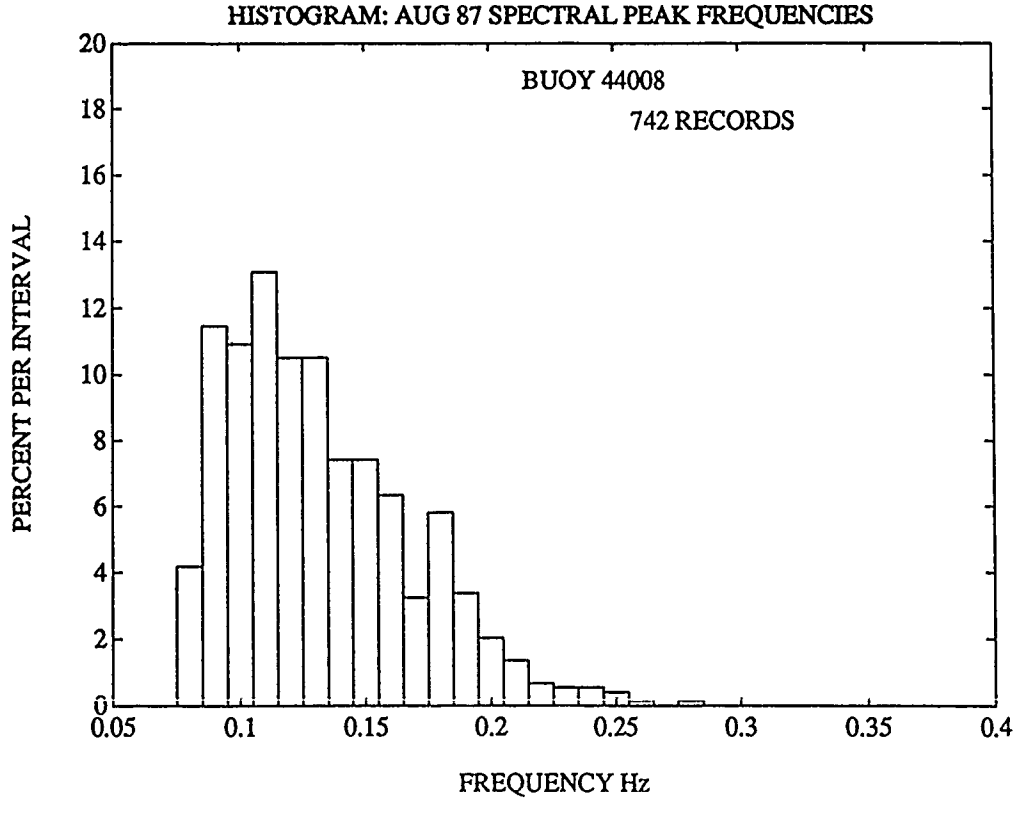
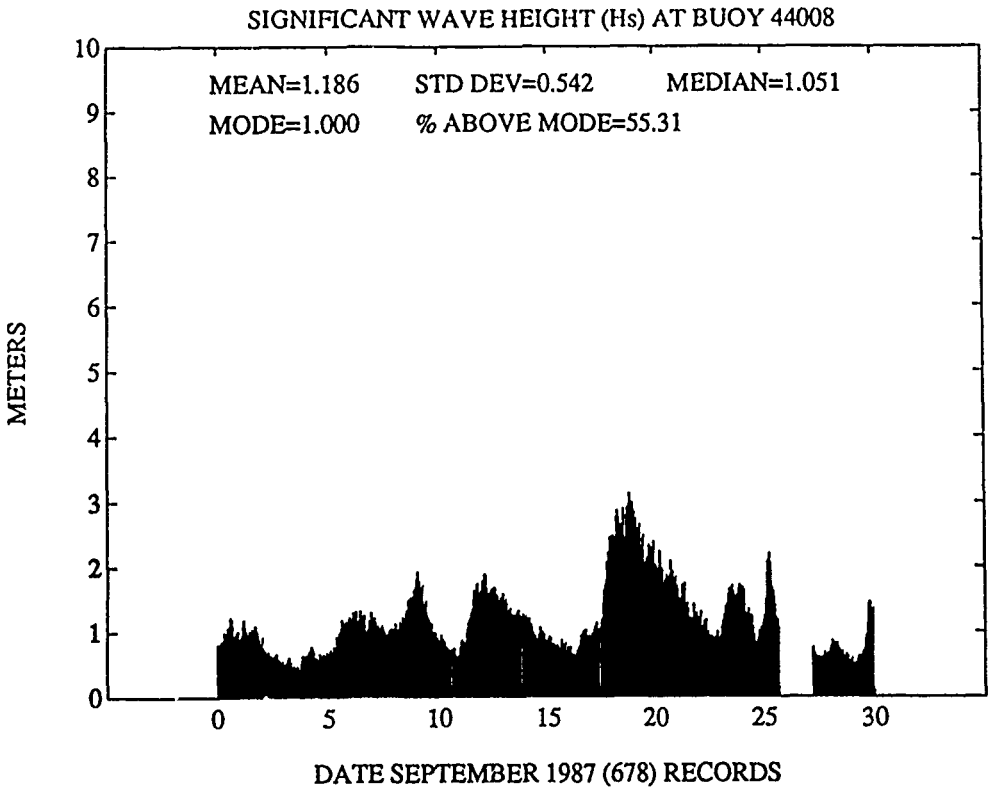


Figure 38: (continued) (e) Spectral peak period time series, and (f) spectral peak frequency distribution.



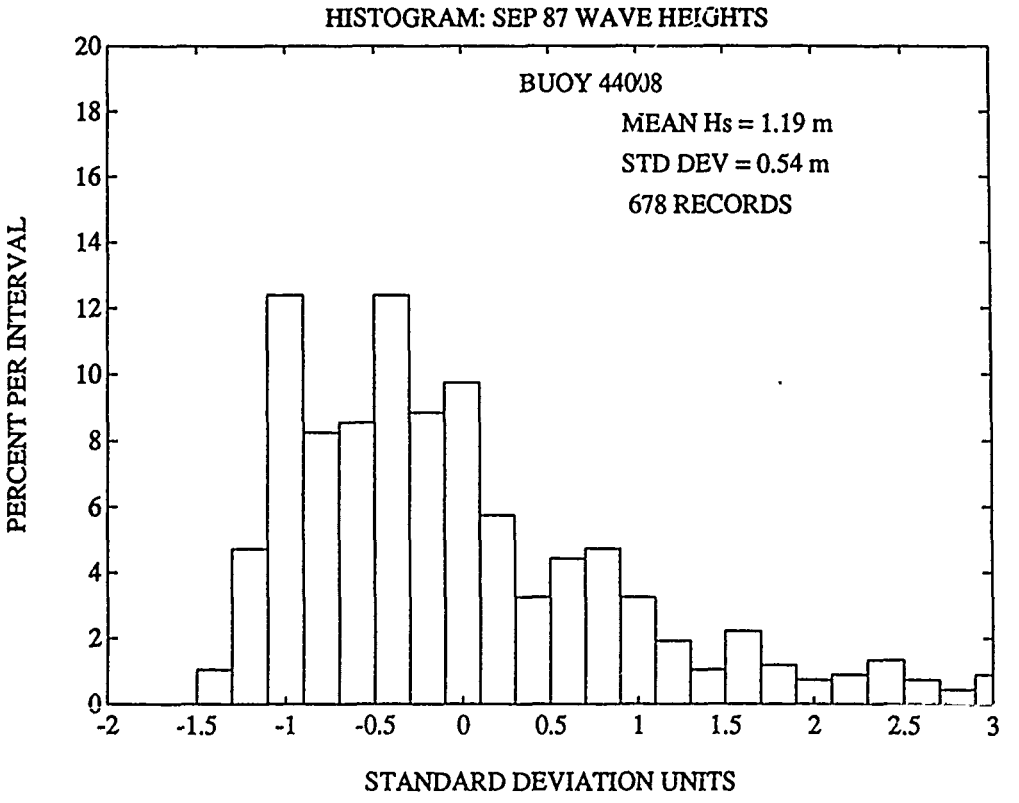
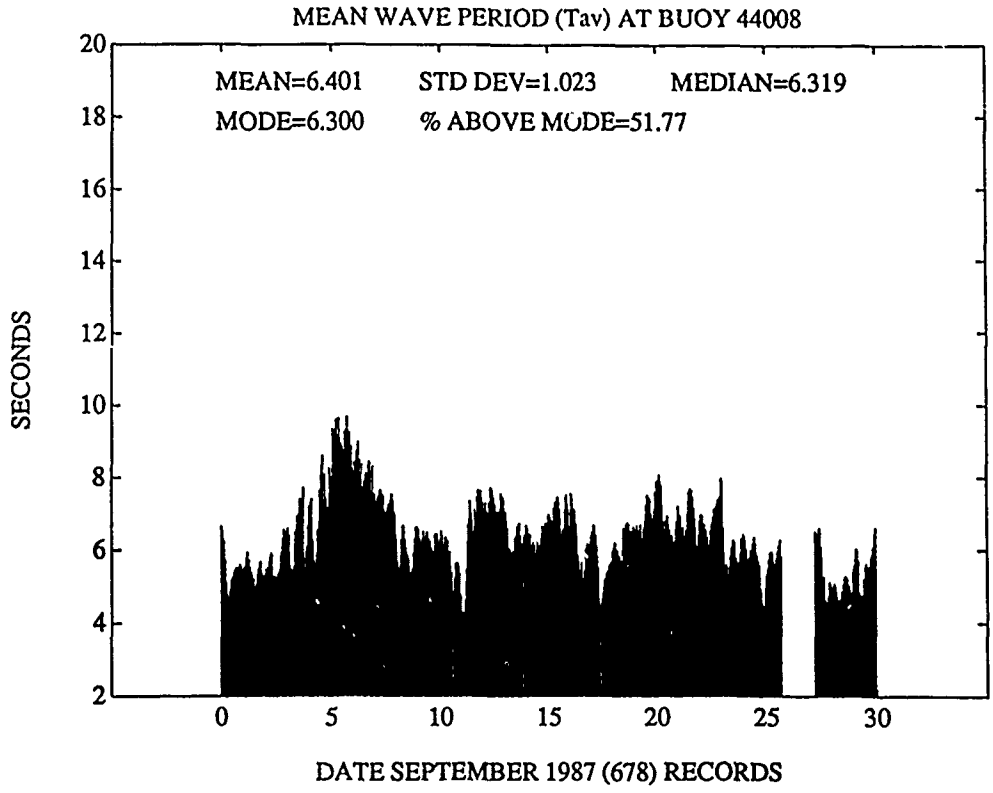


Figure 39: Wave height and period at Buoy 44008, September 1987. (a) Significant wave height time series, and (b) distribution.



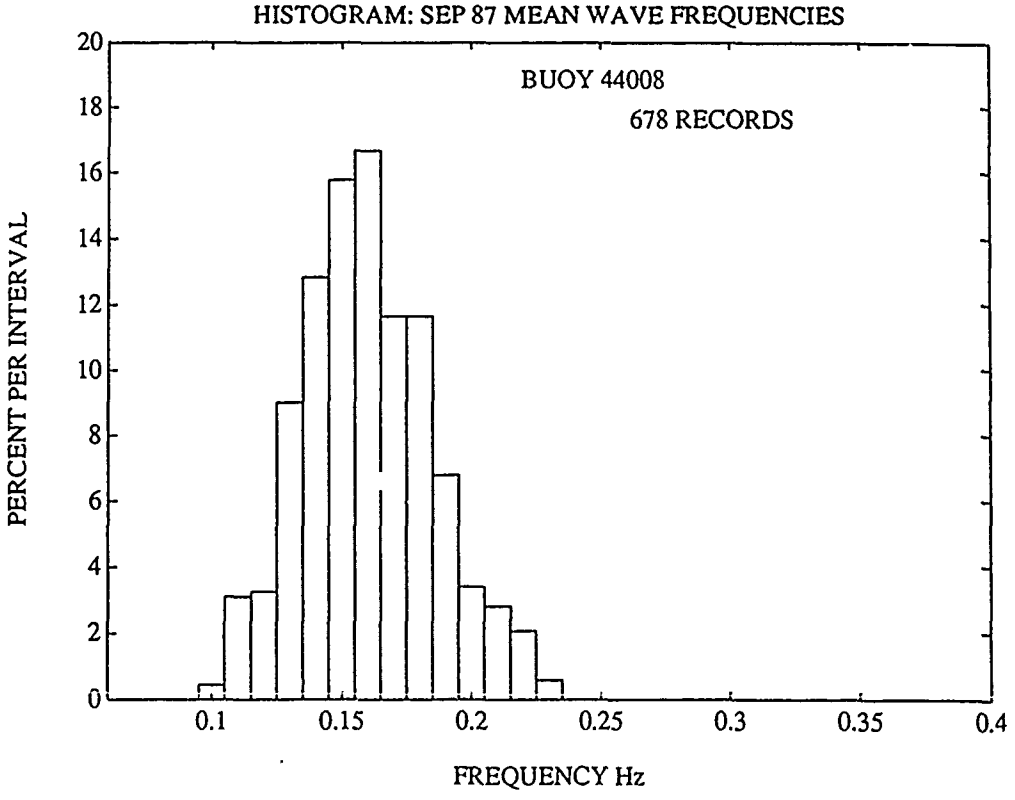
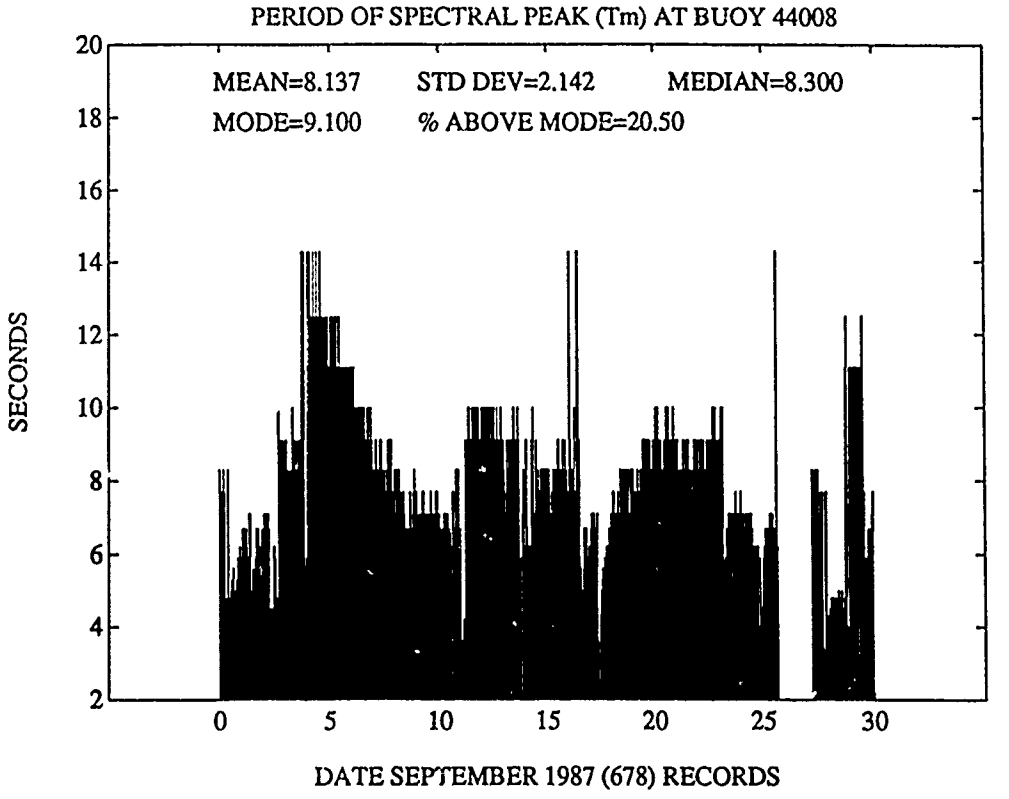


Figure 39: (continued) (c) Mean wave period time series, and (d) mean wave frequency distribution.



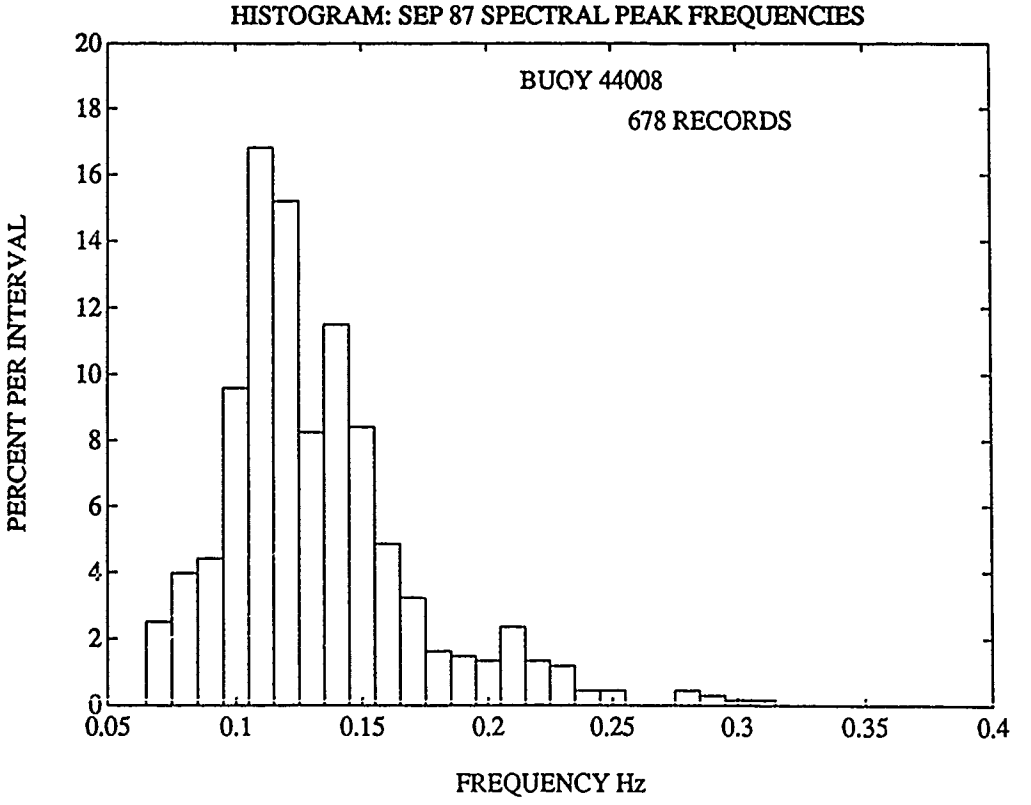


Figure 39: (continued) (e) Spectral peak period time series, and (f) spectral peak frequency distribution.

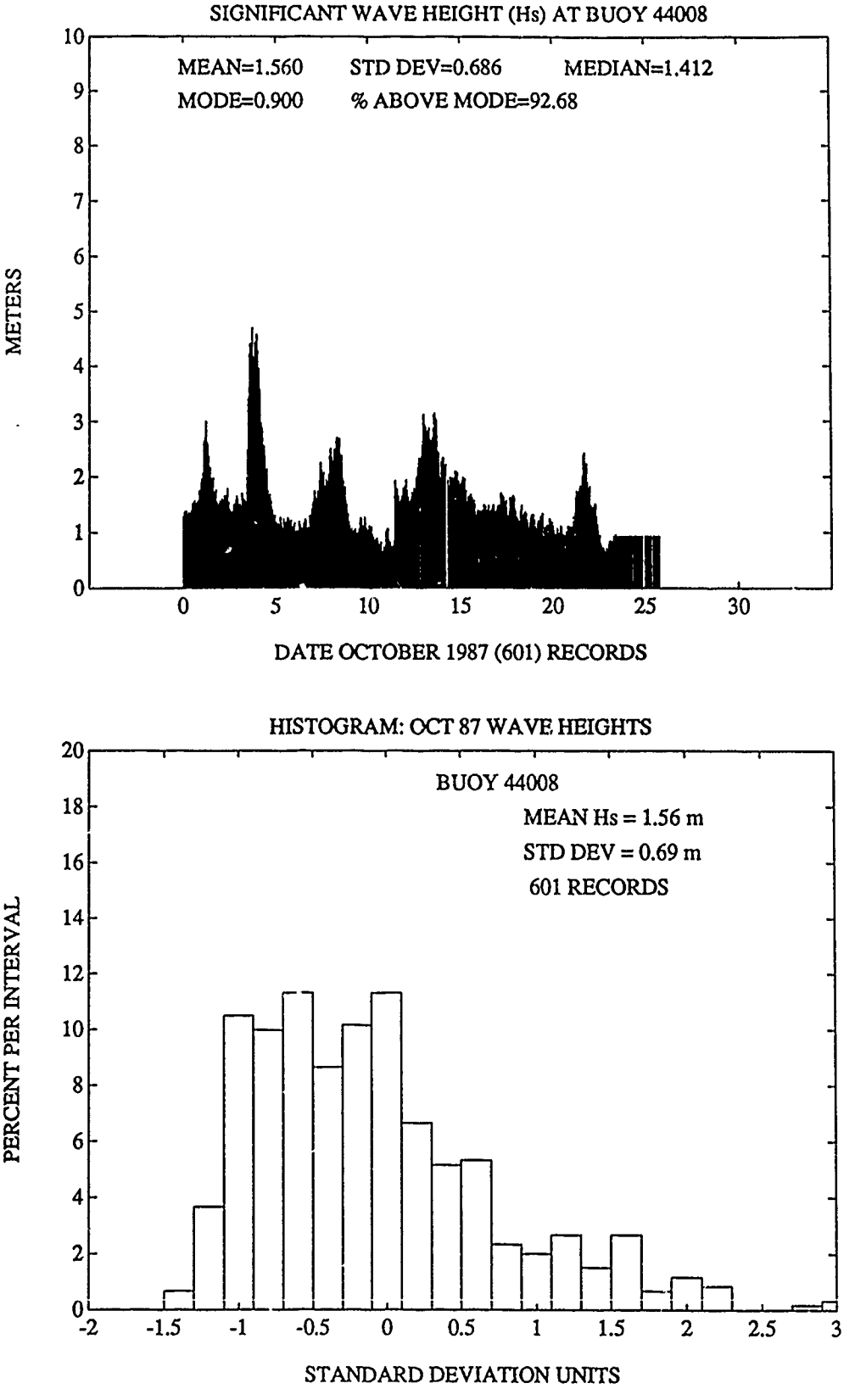
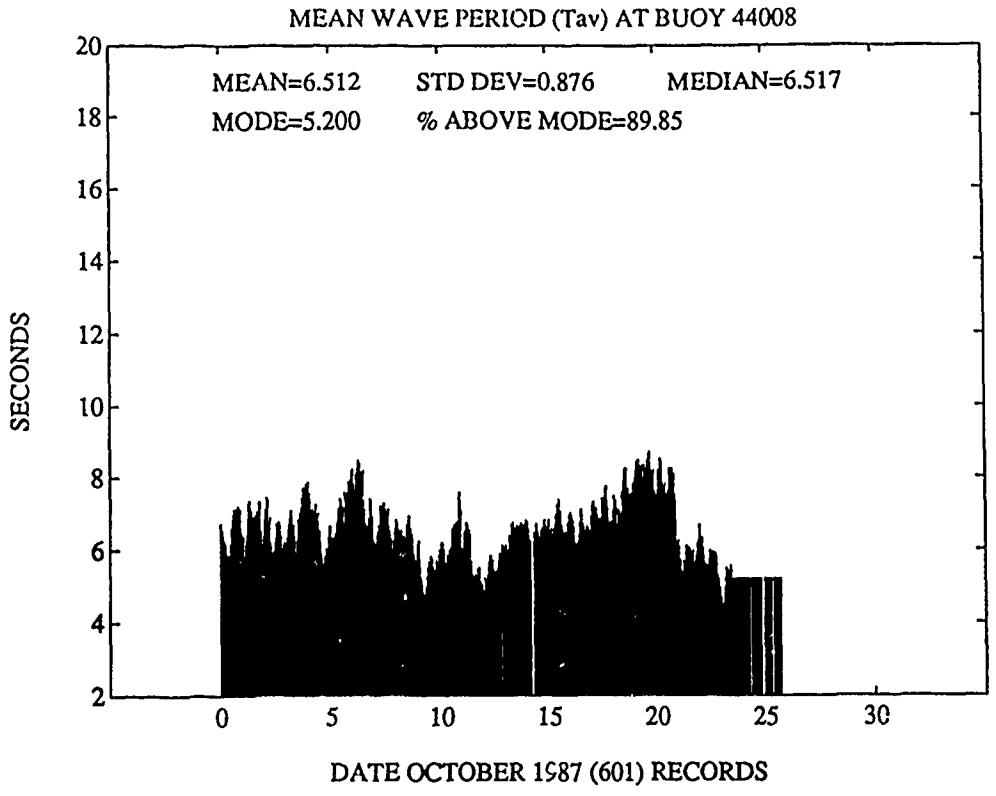


Figure 40: Wave height and period at Buoy 44008, October 1987. (a) Significant wave height time series, and (b) distribution.



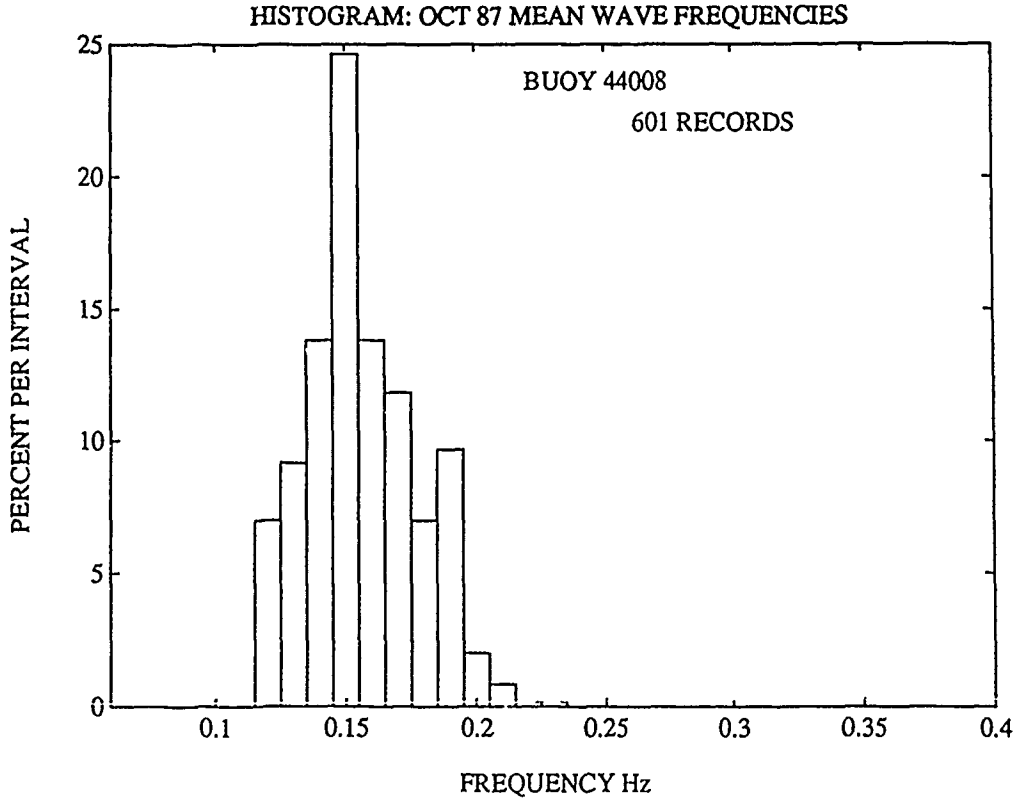
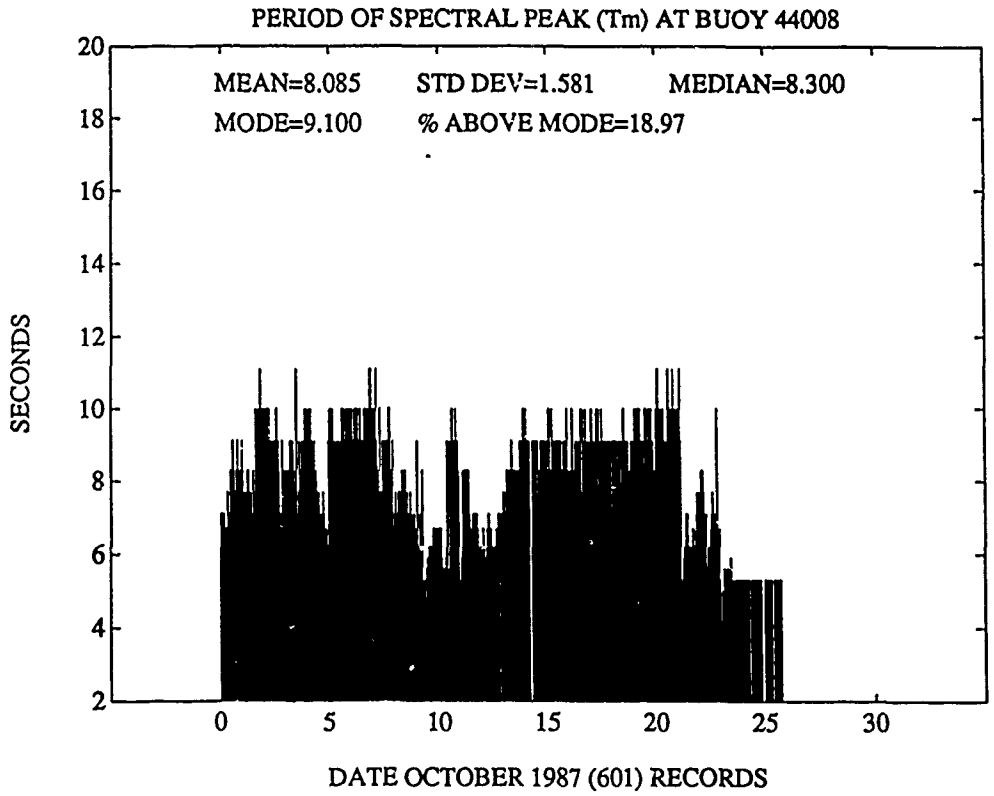


Figure 40: (continued) (c) Mean wave period time series, and (d) mean wave frequency distribution.



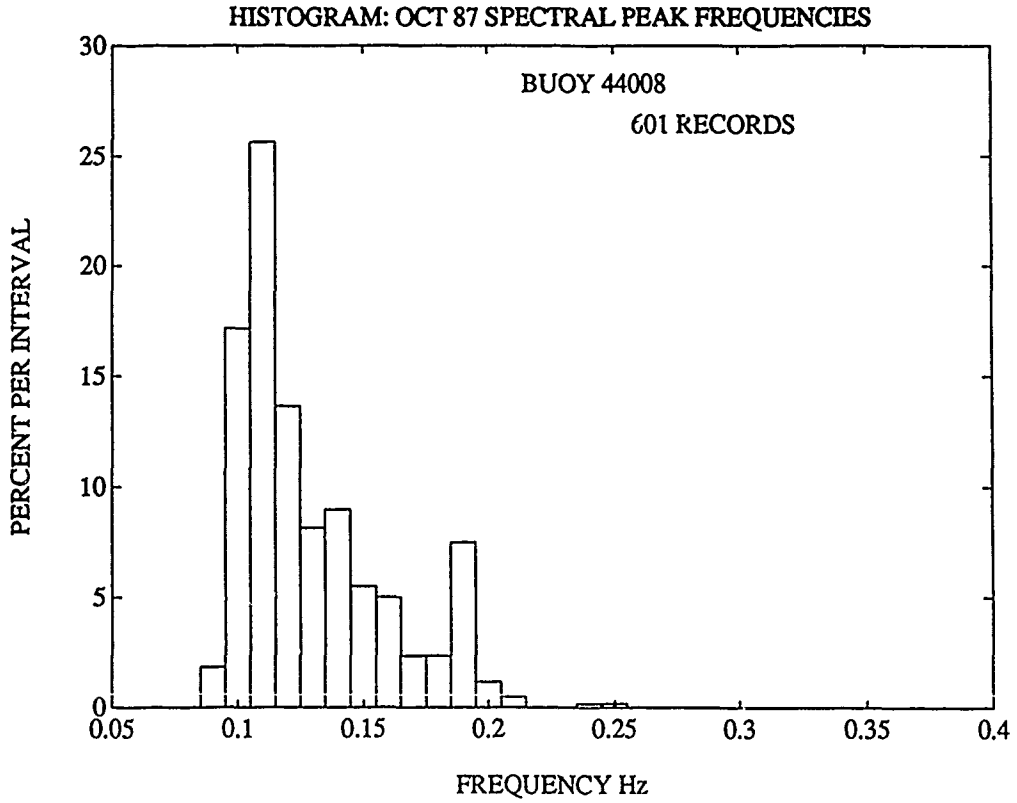
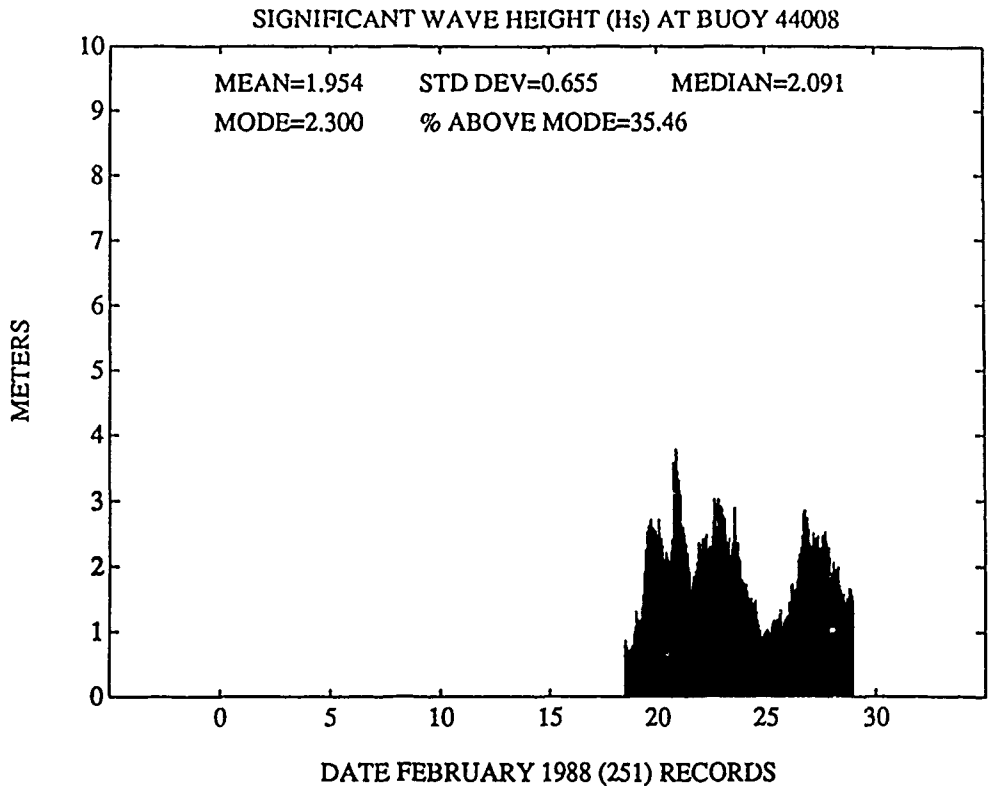


Figure 40: (continued) (e) Spectral peak period time series, and (f) spectral peak frequency distribution.



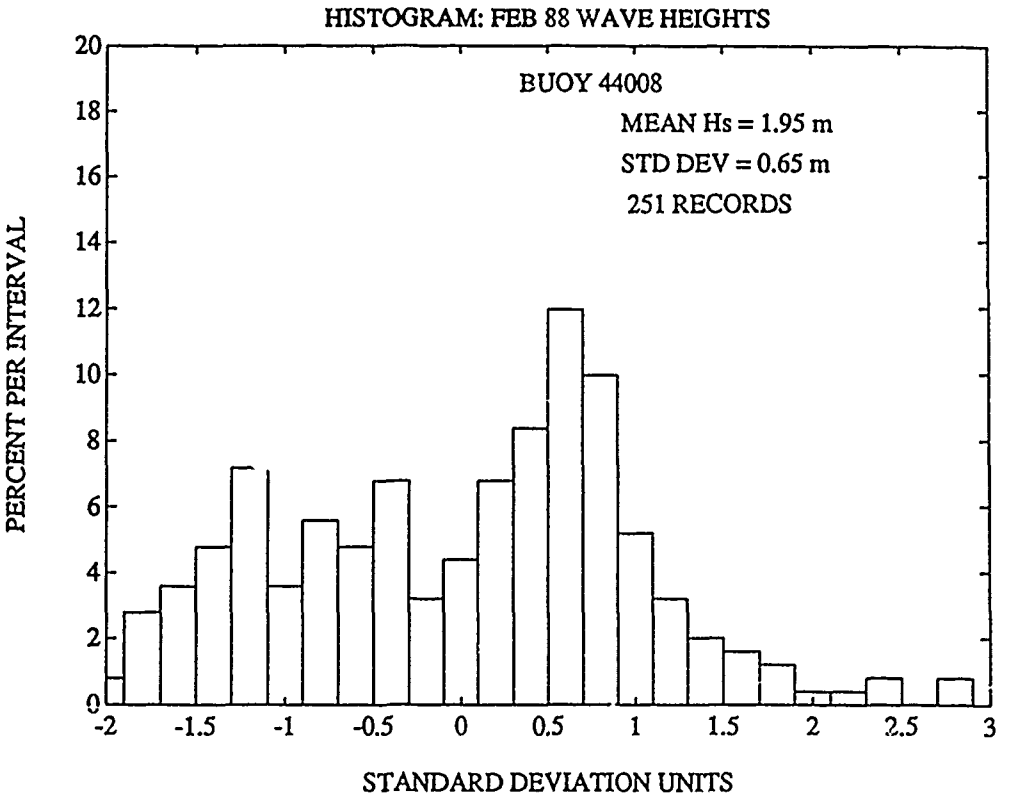
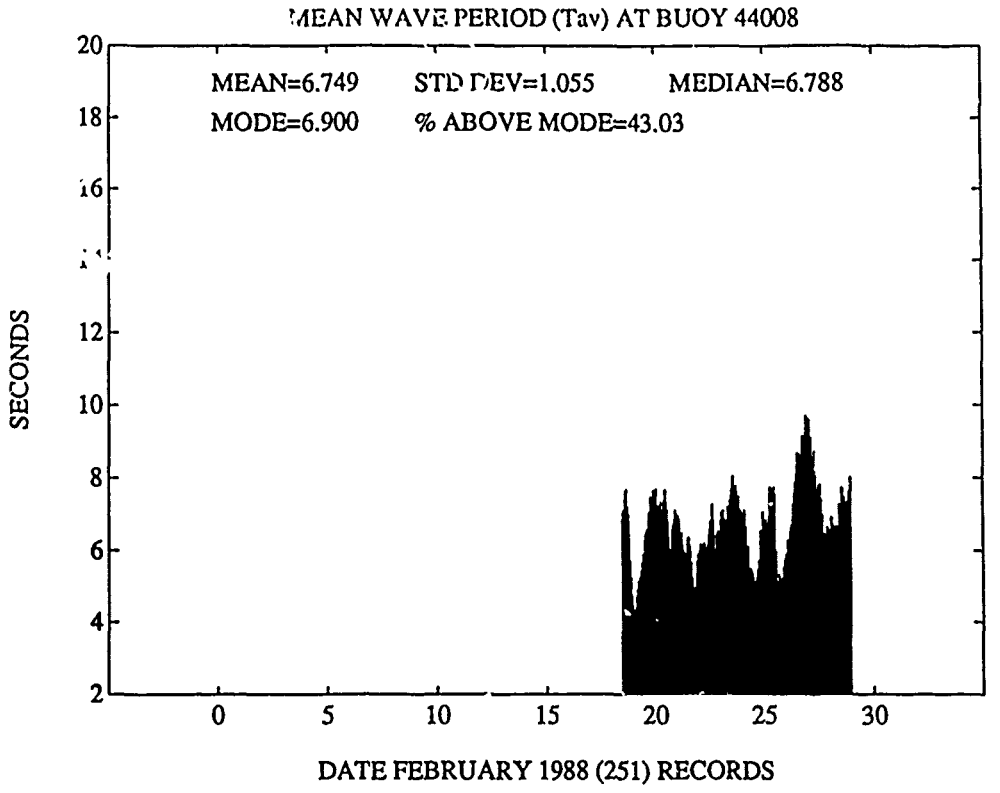


Figure 41: Wave height and period at Buoy 44008, February 1988. (a) Significant wave height time series, and (b) distribution.



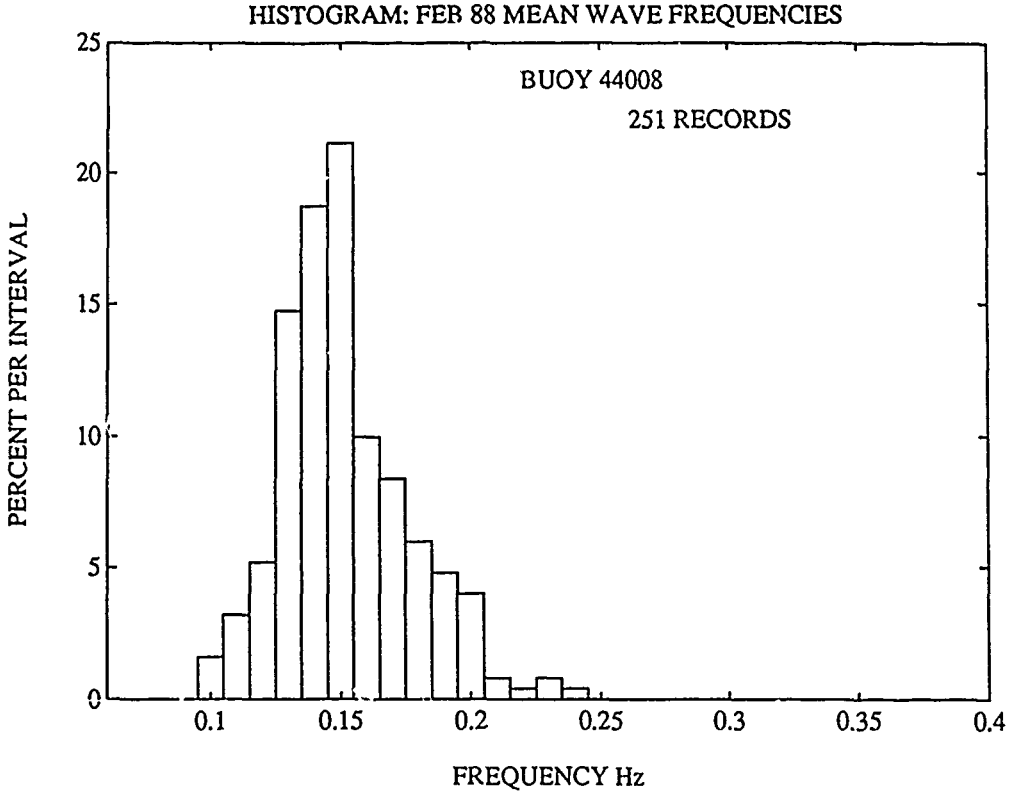
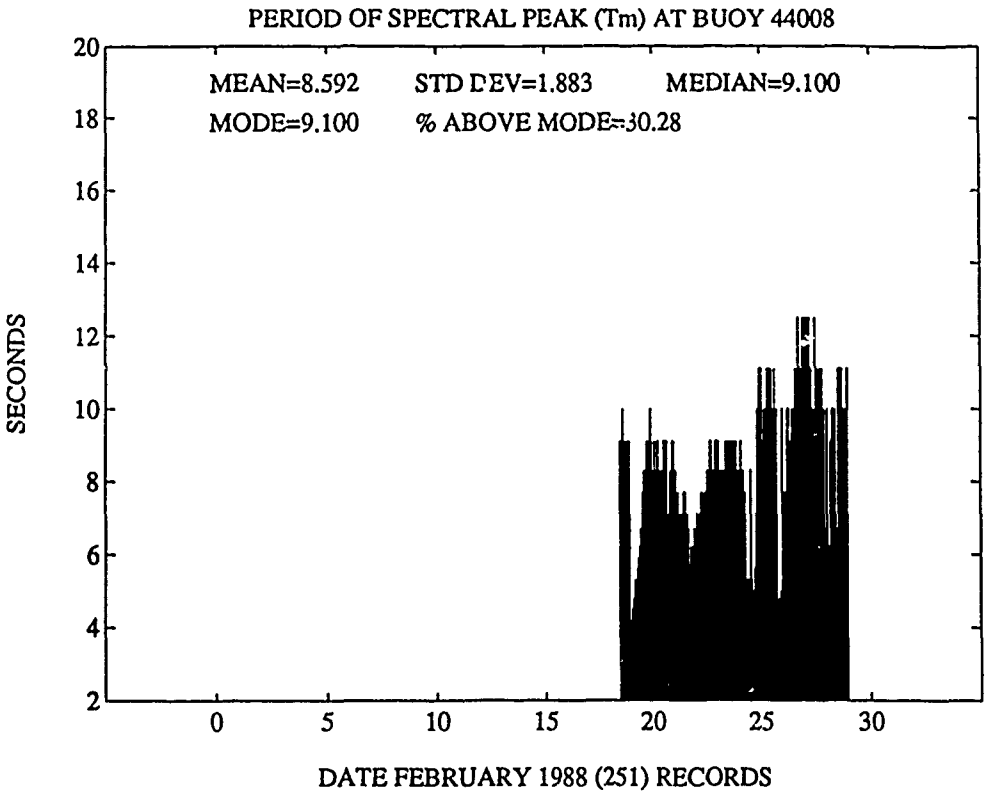


Figure 41: (continued) (c) Mean wave period time series, and (d) mean wave frequency distribution.



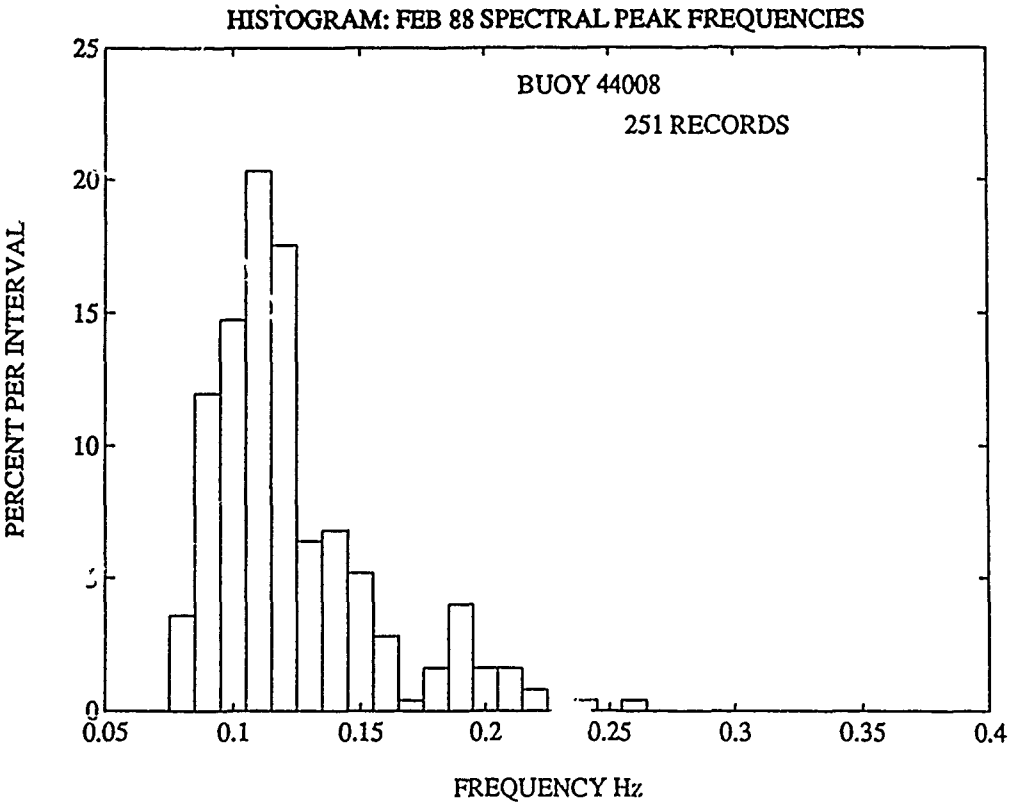


Figure 41: (continued) (e) Spectral peak period time series, and (f) spectral peak frequency distribution.

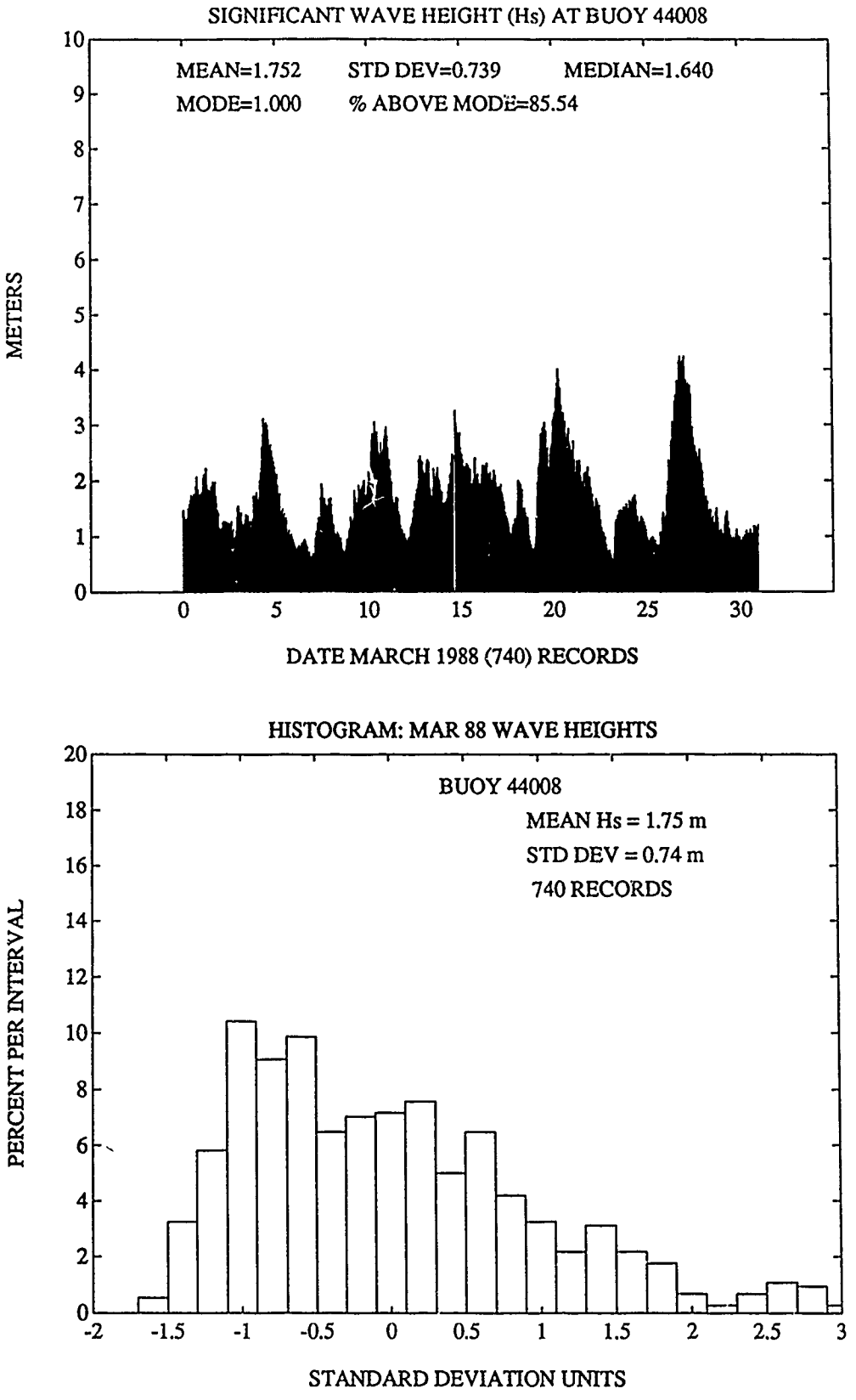
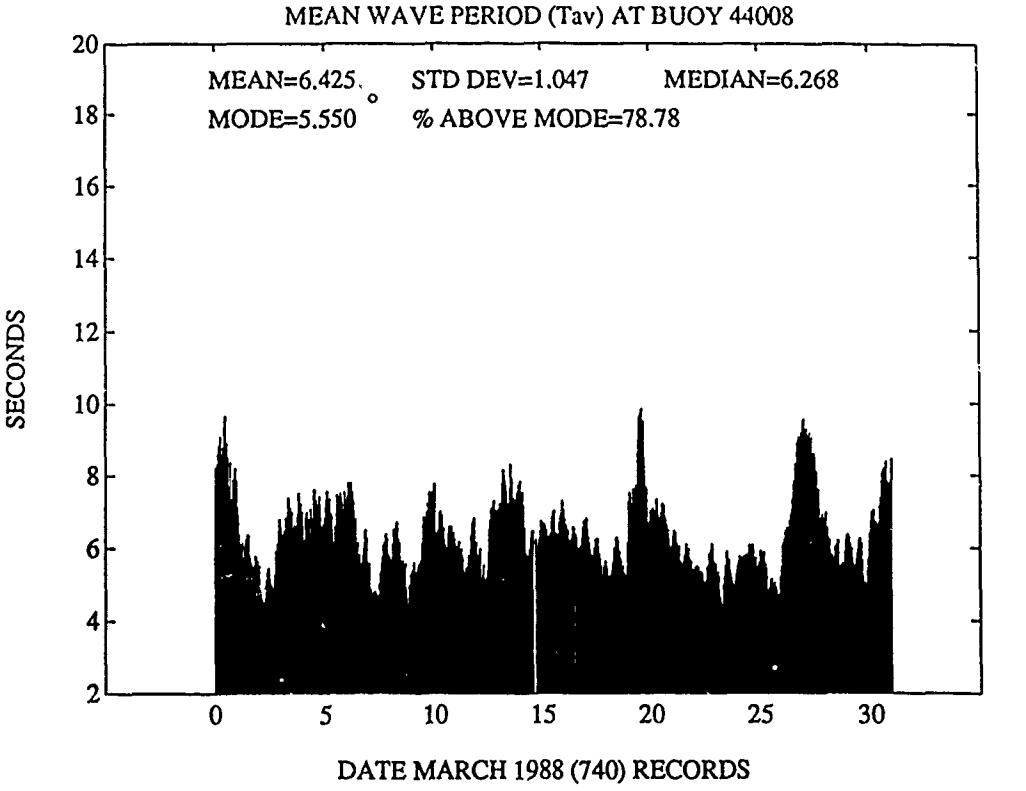


Figure 42: Wave height and period at Buoy 44008, March 1988. (a) Significant wave height time series, and (b) distribution.



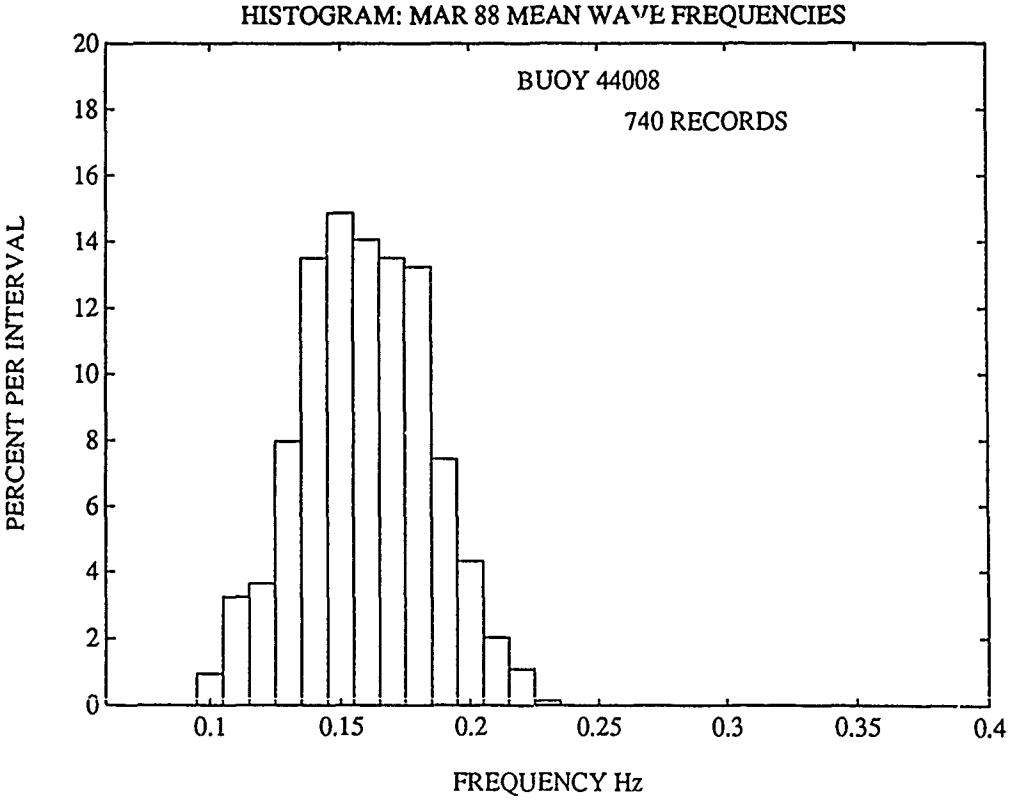
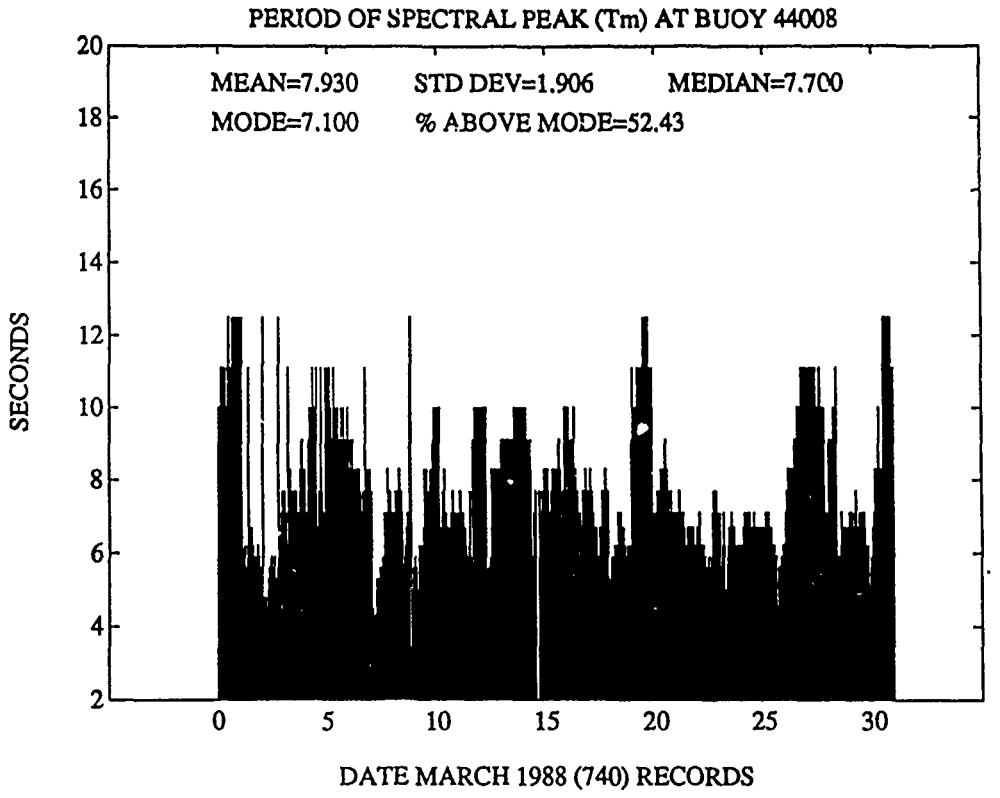


Figure 42: (continued) (c) Mean wave period time series, and (d) mean wave frequency distribution.



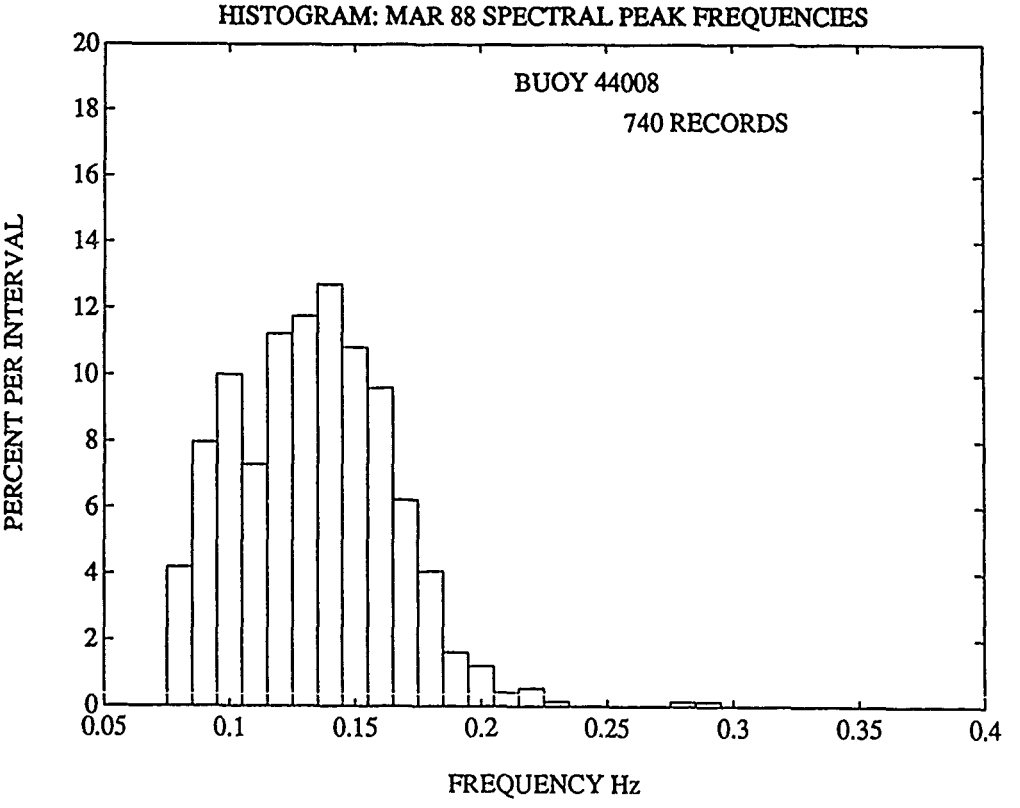


Figure 42: (continued) (e) Spectral peak period time series, and (f) spectral peak frequency distribution.

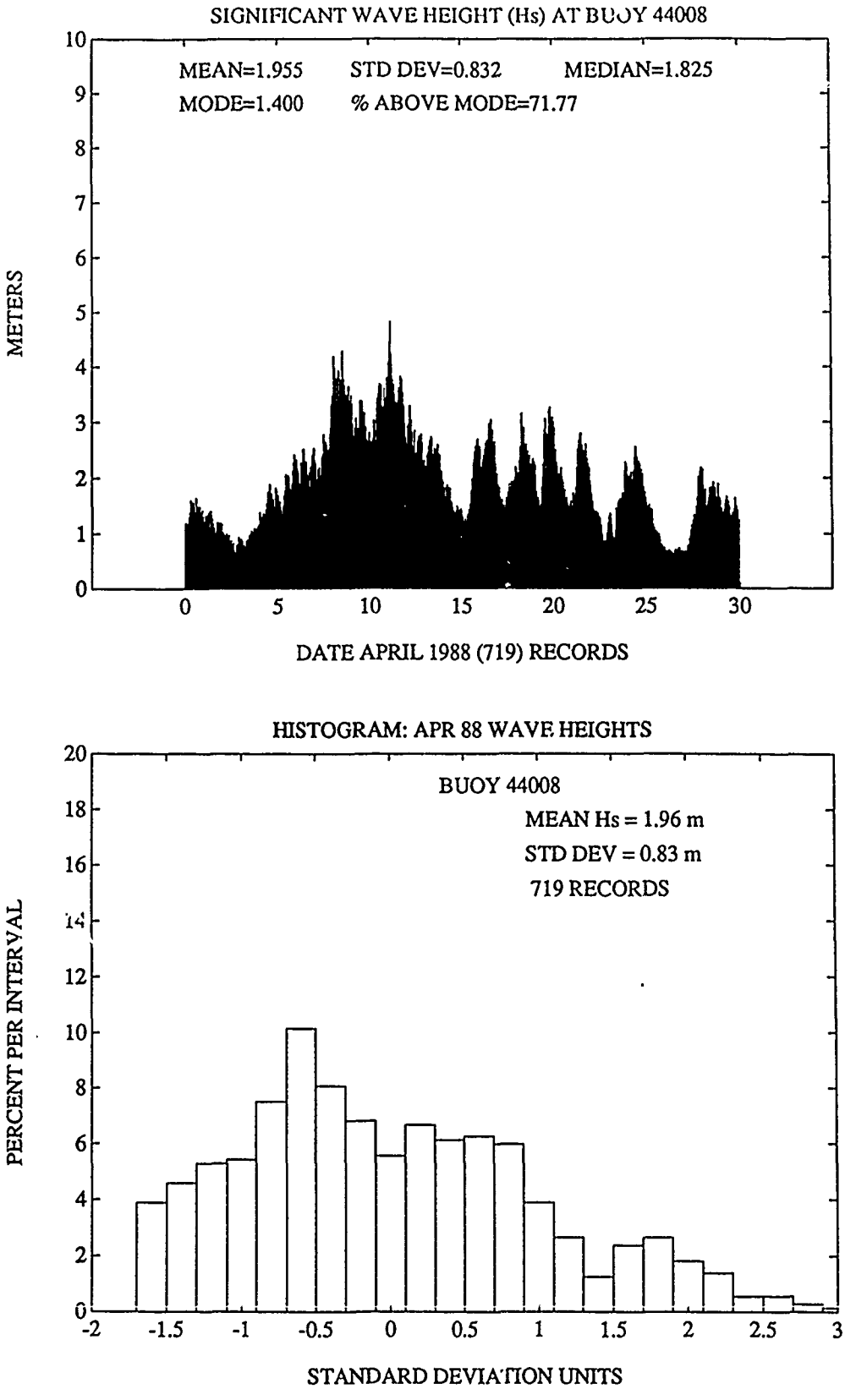
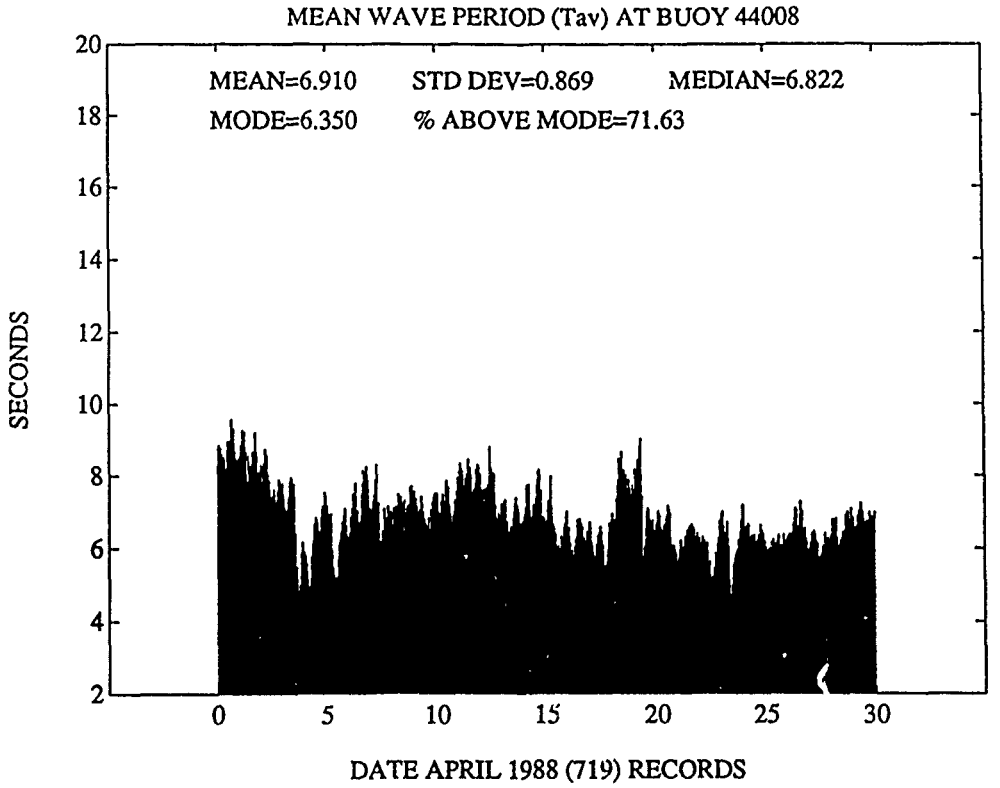


Figure 43: Wave height and period at Buoy 44008, April 1988. (a) Significant wave height time series, and (b) distribution.



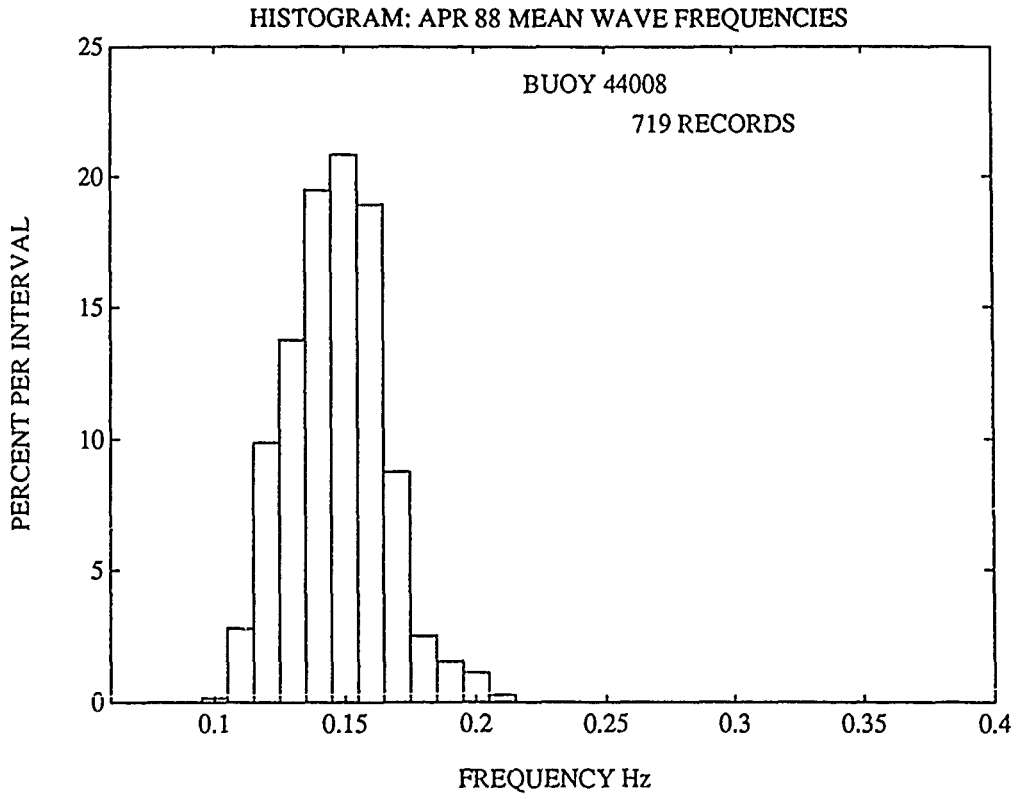
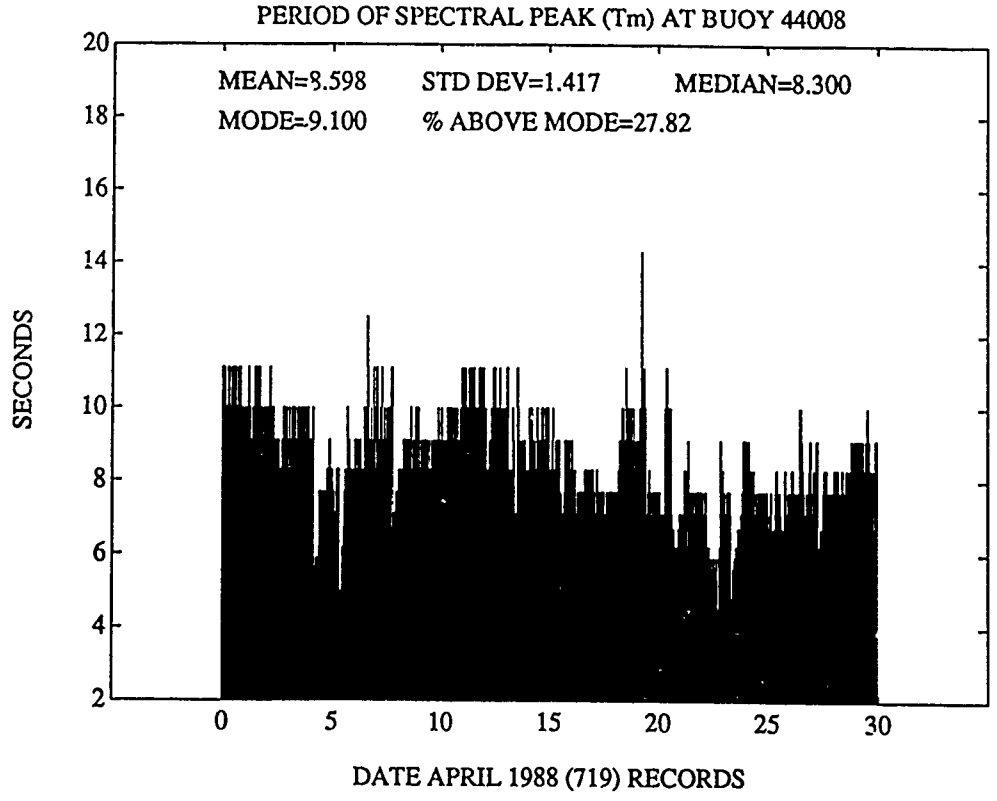


Figure 43: (continued) (c) Mean wave period time series, and (d) mean wave frequency distribution.



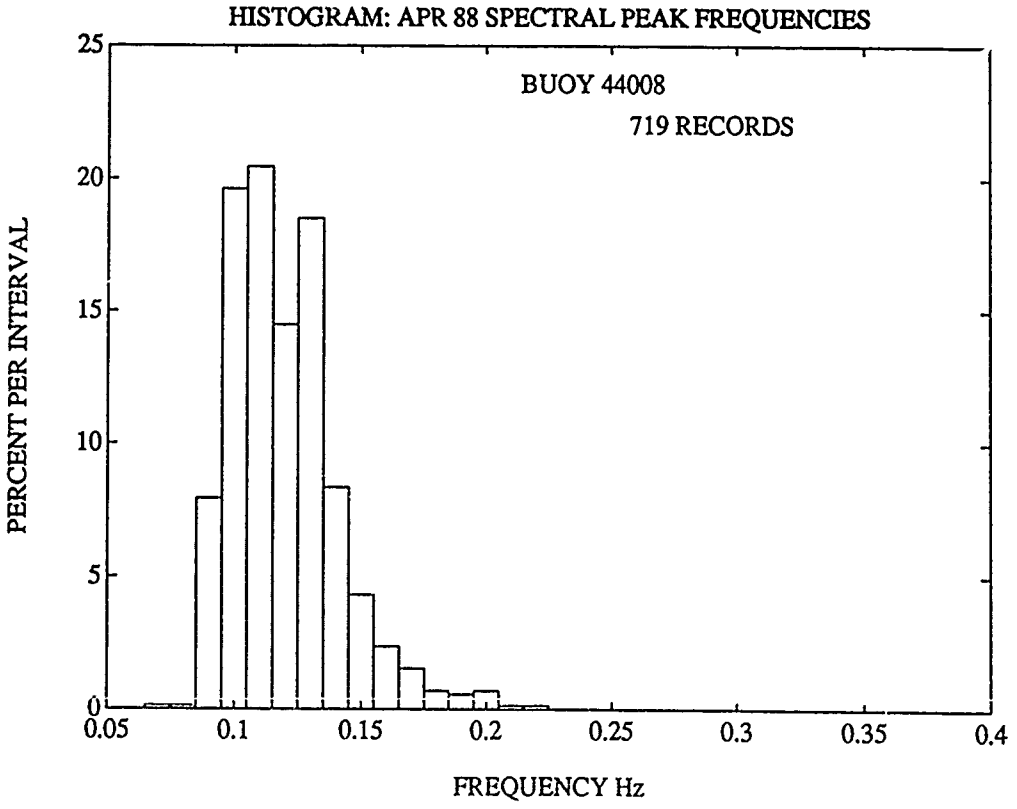
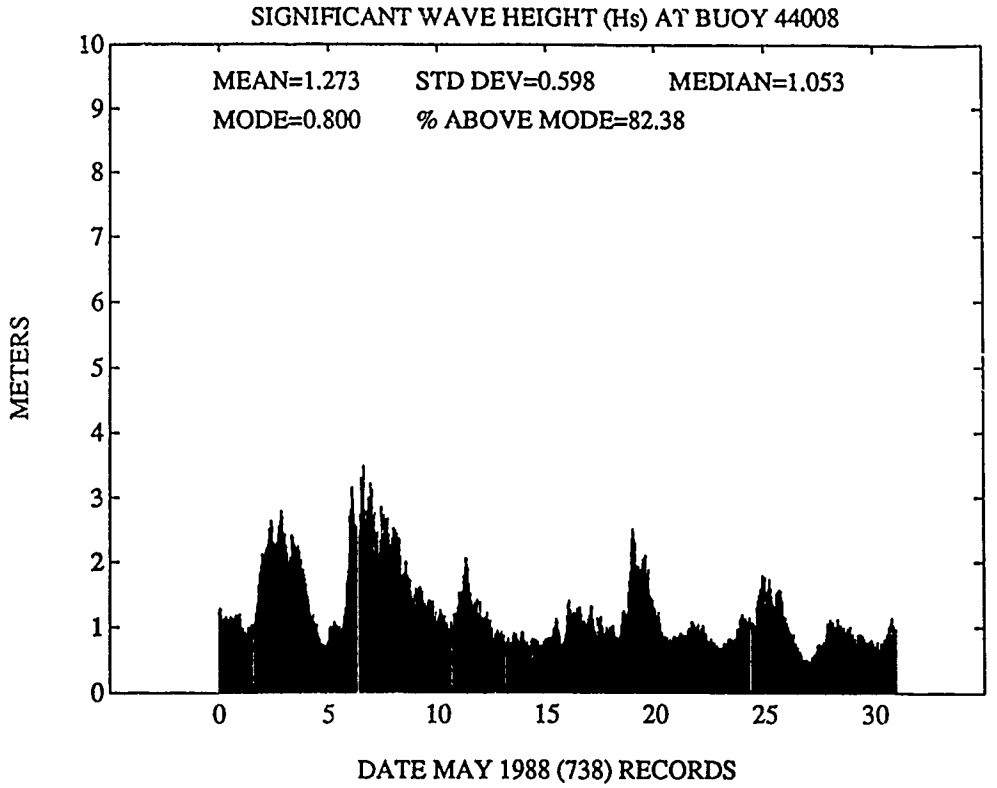


Figure 43: (continued) (e) Spectral peak period time series, and (f) spectral peak frequency distribution.



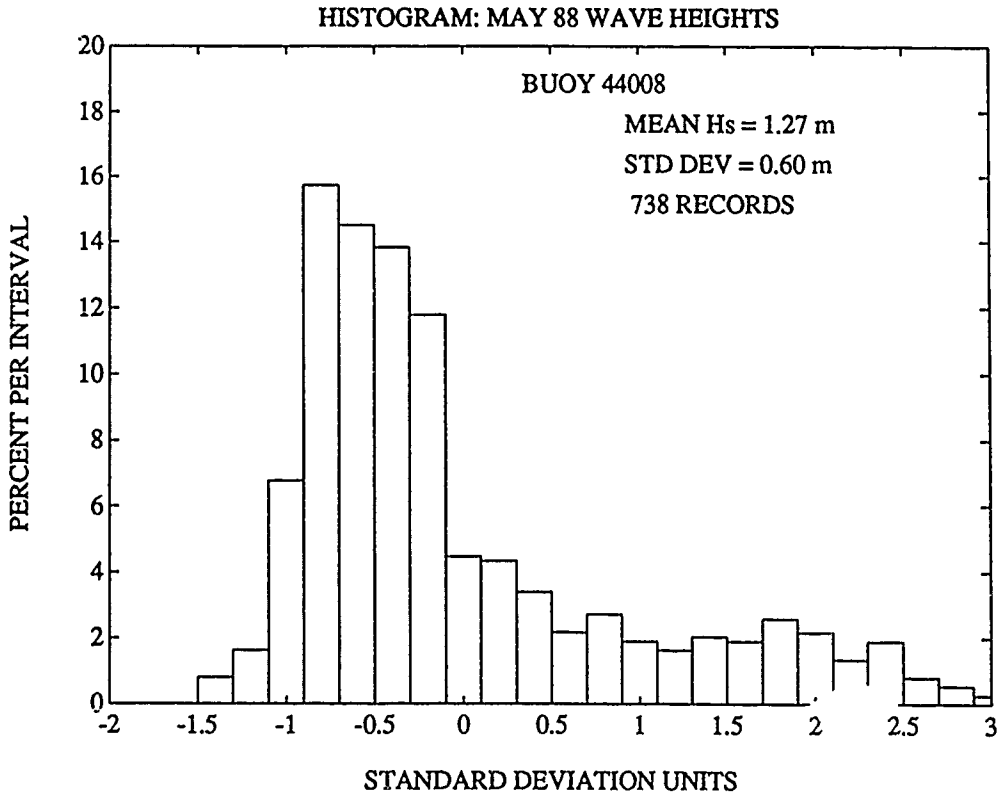
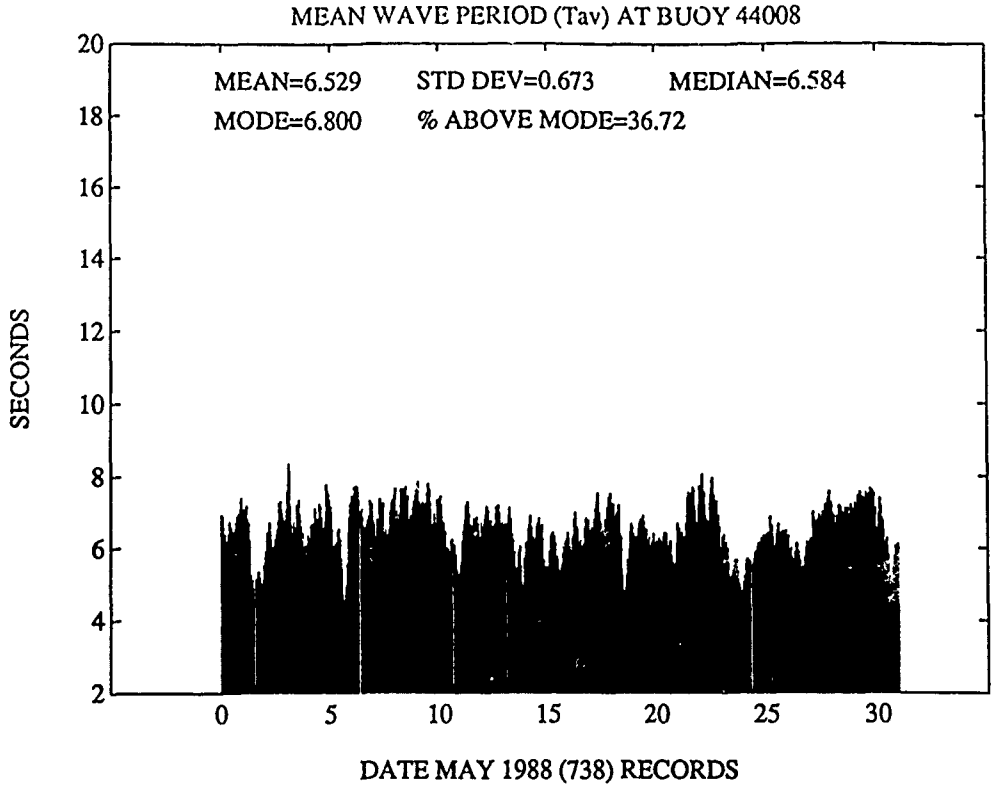


Figure 44: Wave height and period at Buoy 44008, May 1988. (a) Significant wave height time series, and (b) distribution.



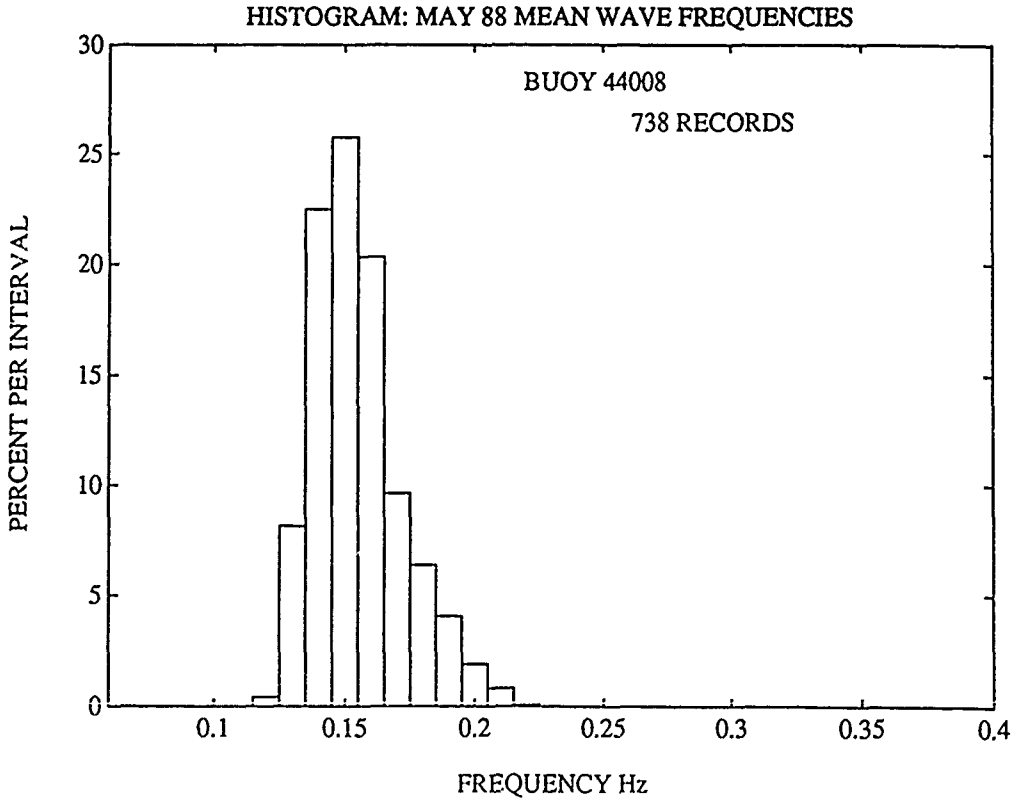
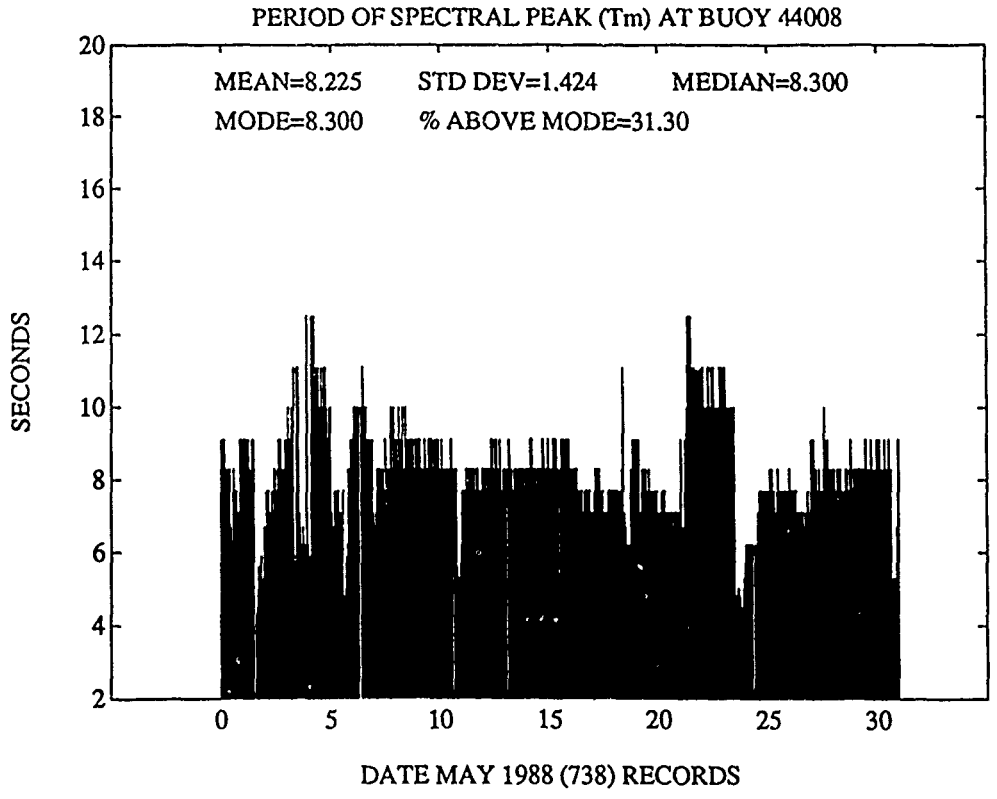


Figure 44: (continued) (c) Mean wave period time series, and (d) mean wave frequency distribution.



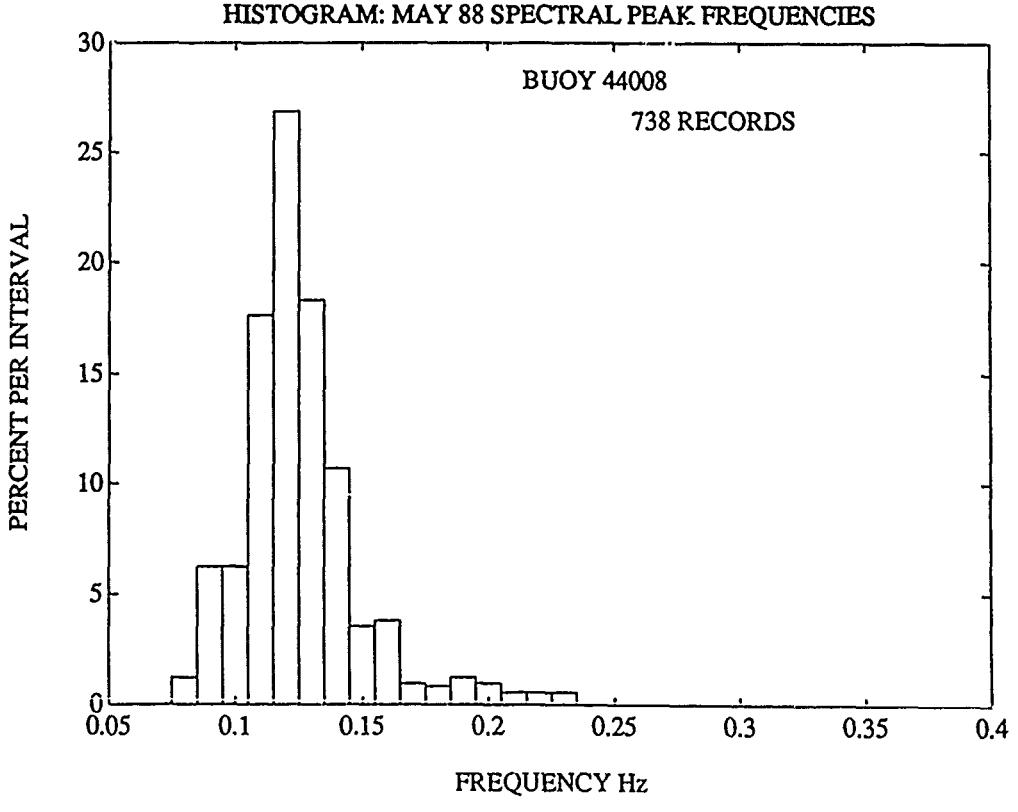


Figure 44: (continued) (e) Spectral peak period time series, and (f) spectral peak frequency distribution.

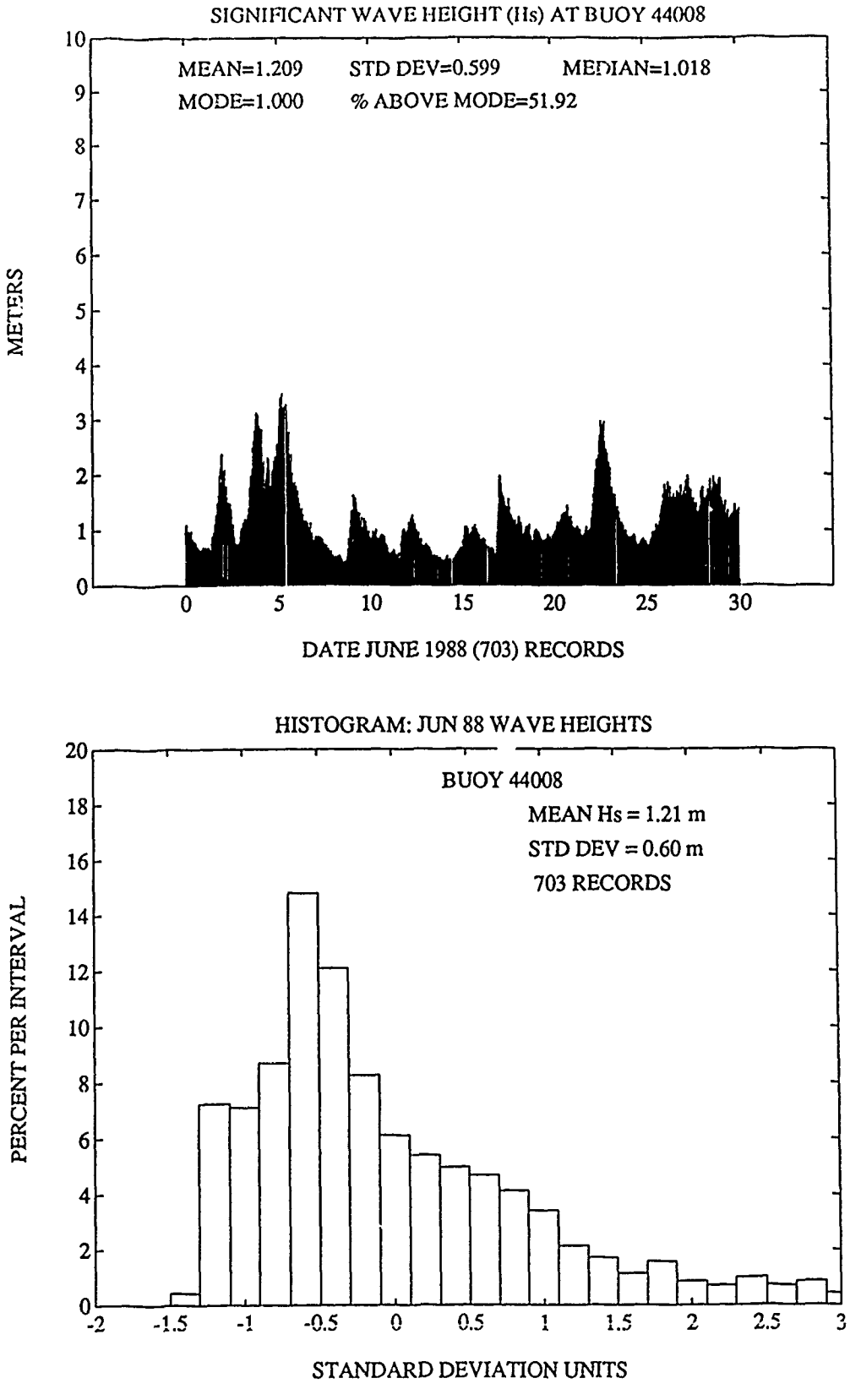
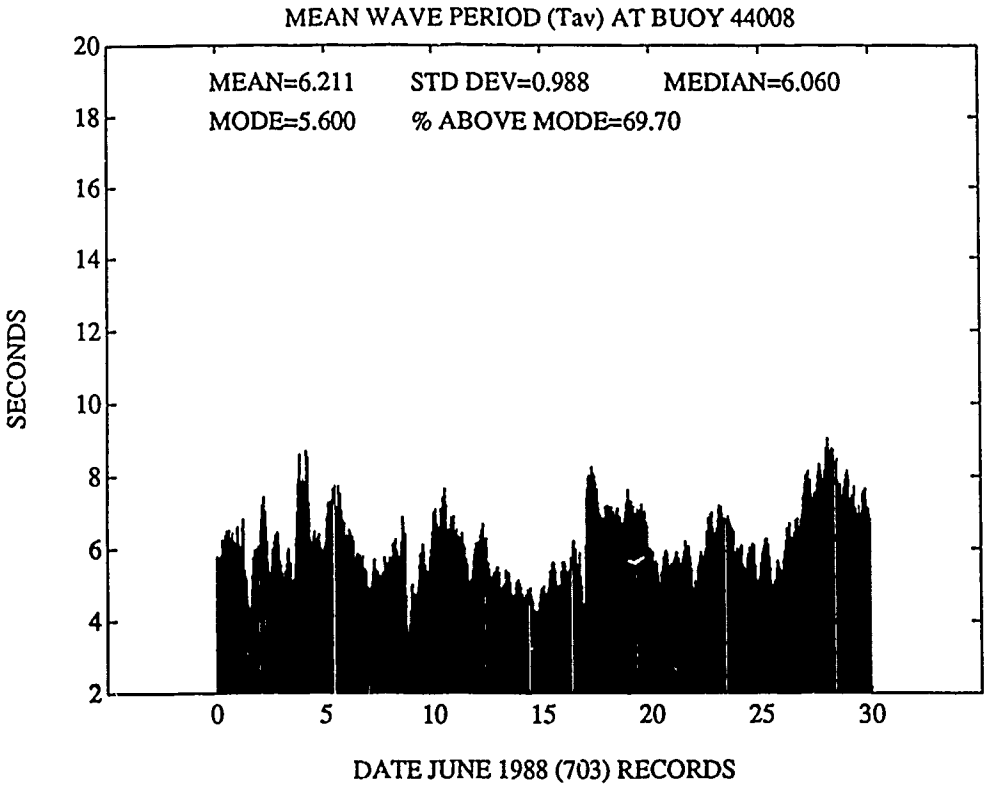


Figure 45: Wave height and period at Buoy 44008, June 1988. (a) Significant wave height time series, and (b) distribution.



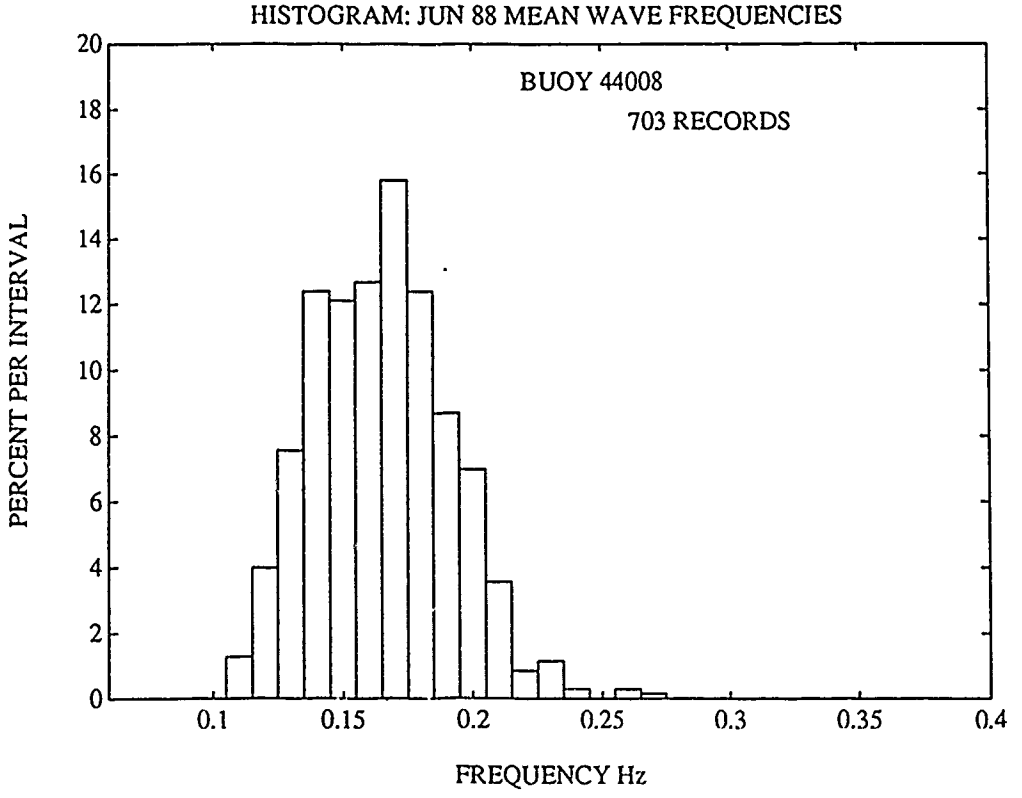
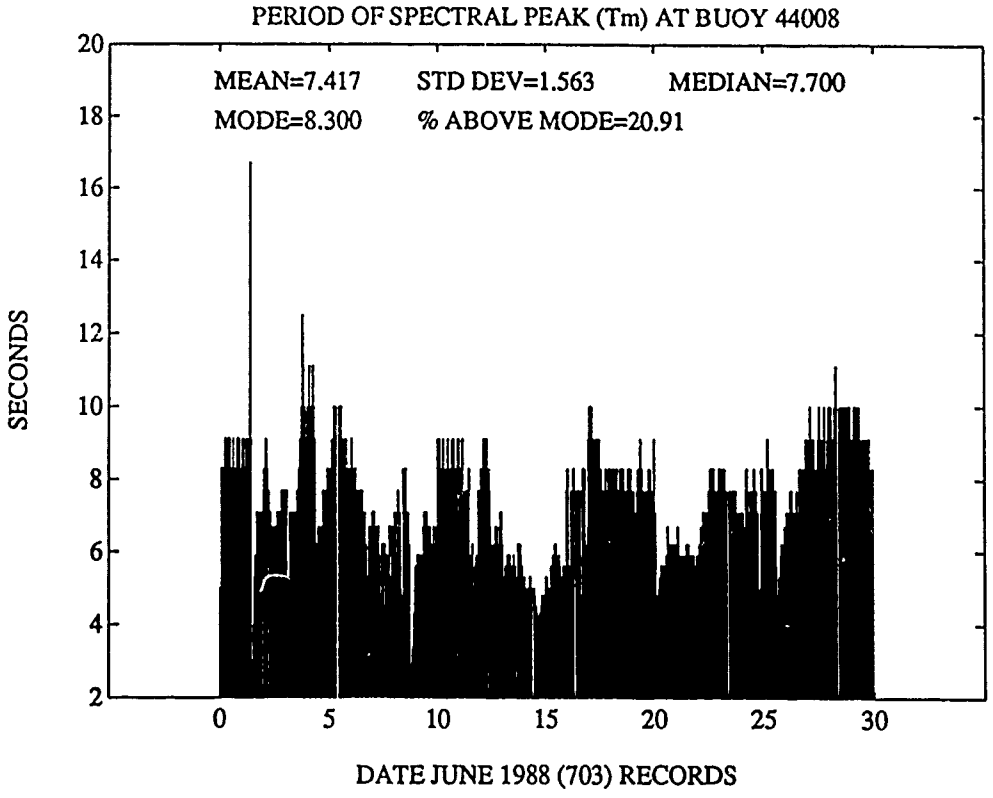


Figure 45: (continued) (c) Mean wave period time series, and (d) mean wave frequency distribution.



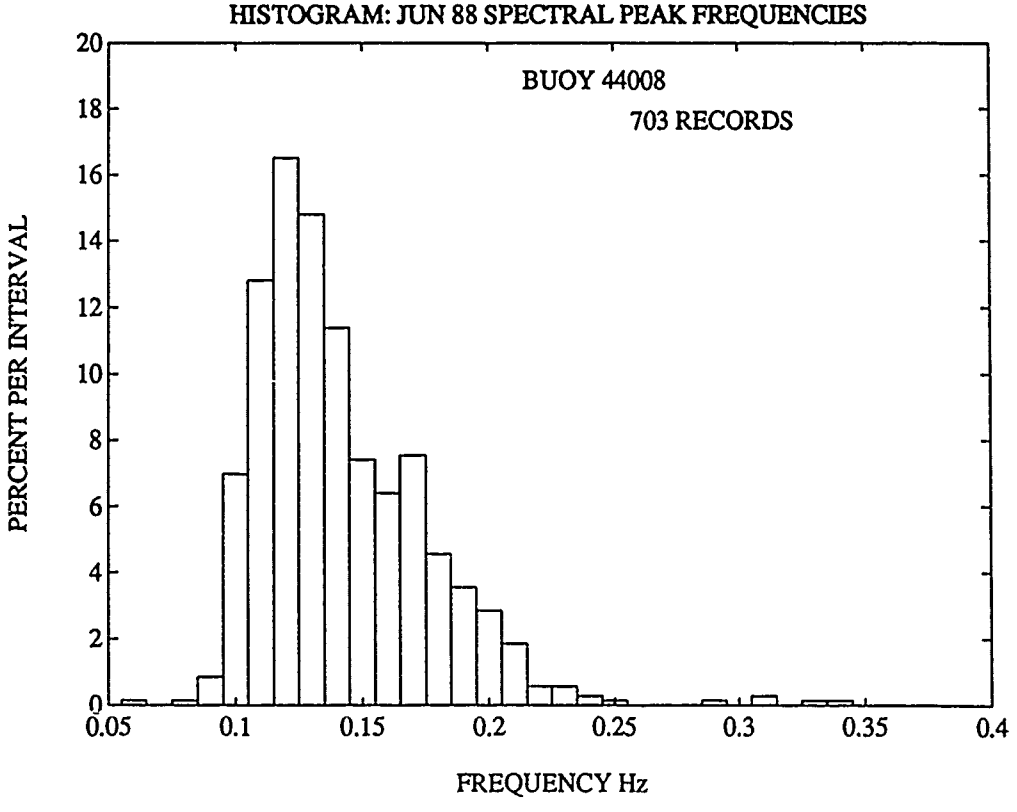
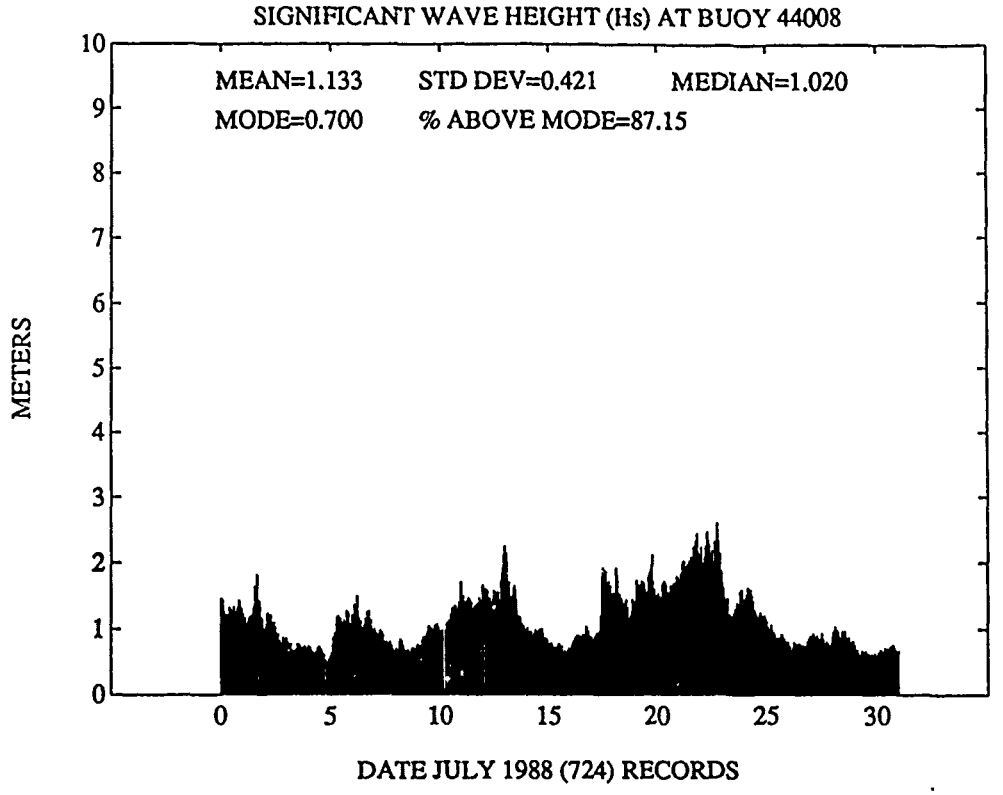


Figure 45: (continued) (e) Spectral peak period time series, and (f) spectral peak frequency distribution.



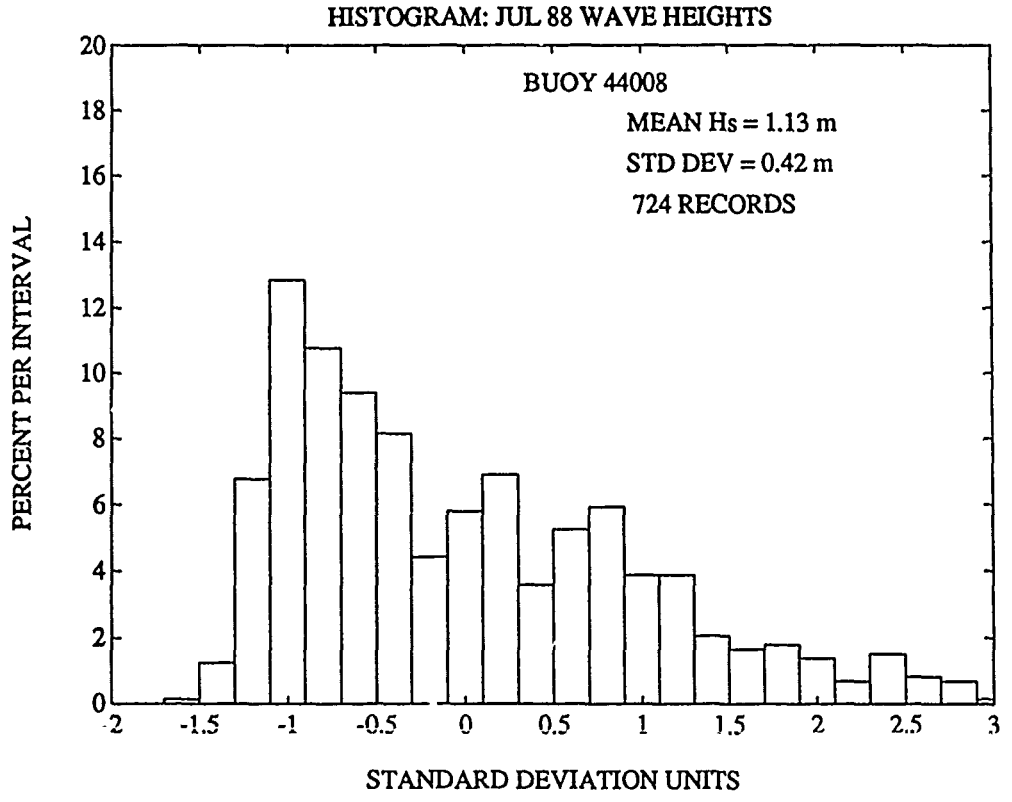
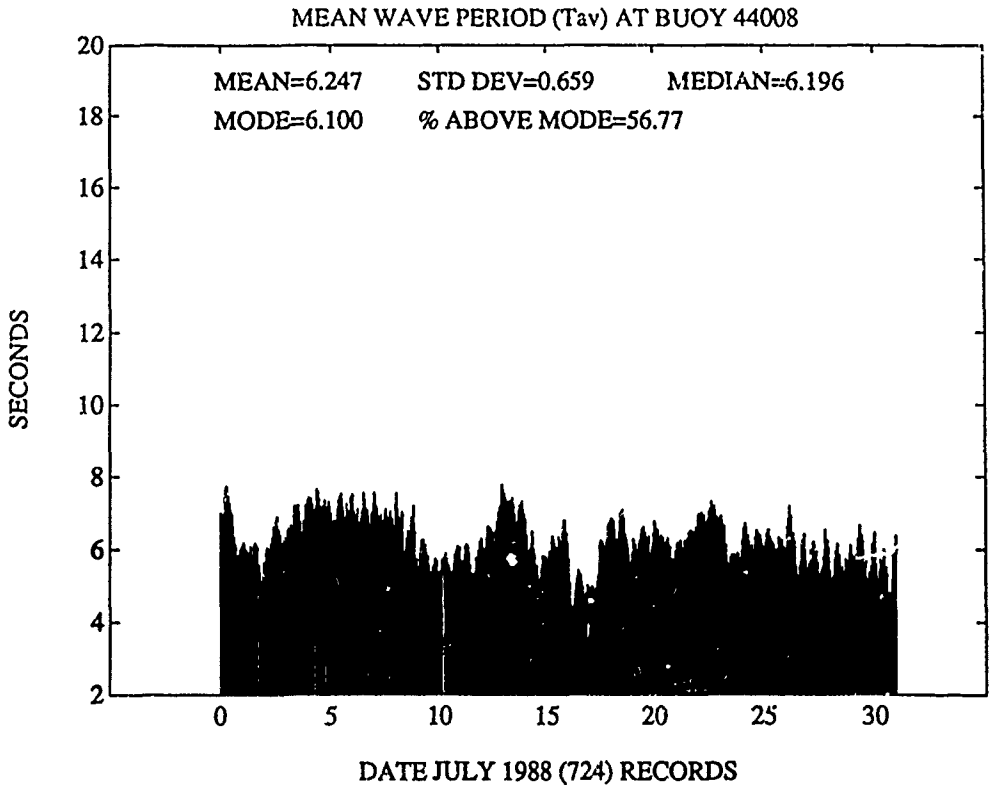


Figure 46: Wave height and period at Buoy 44008, July 1988. (a) Significant wave height time series, and (b) distribution.



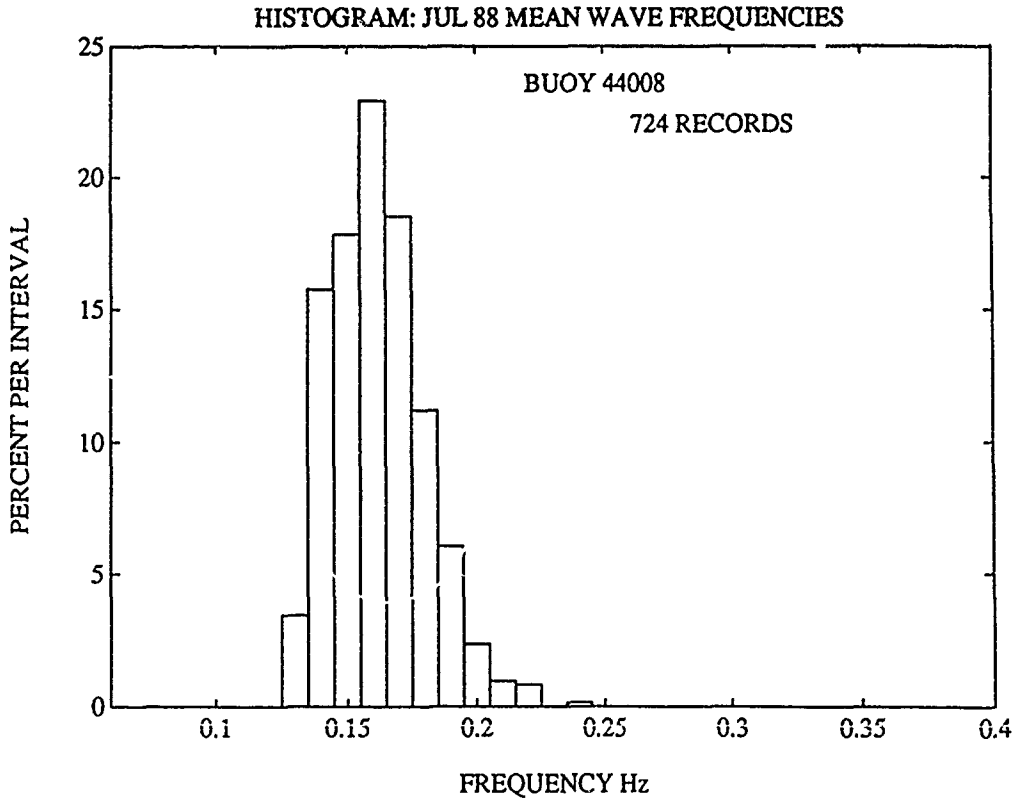
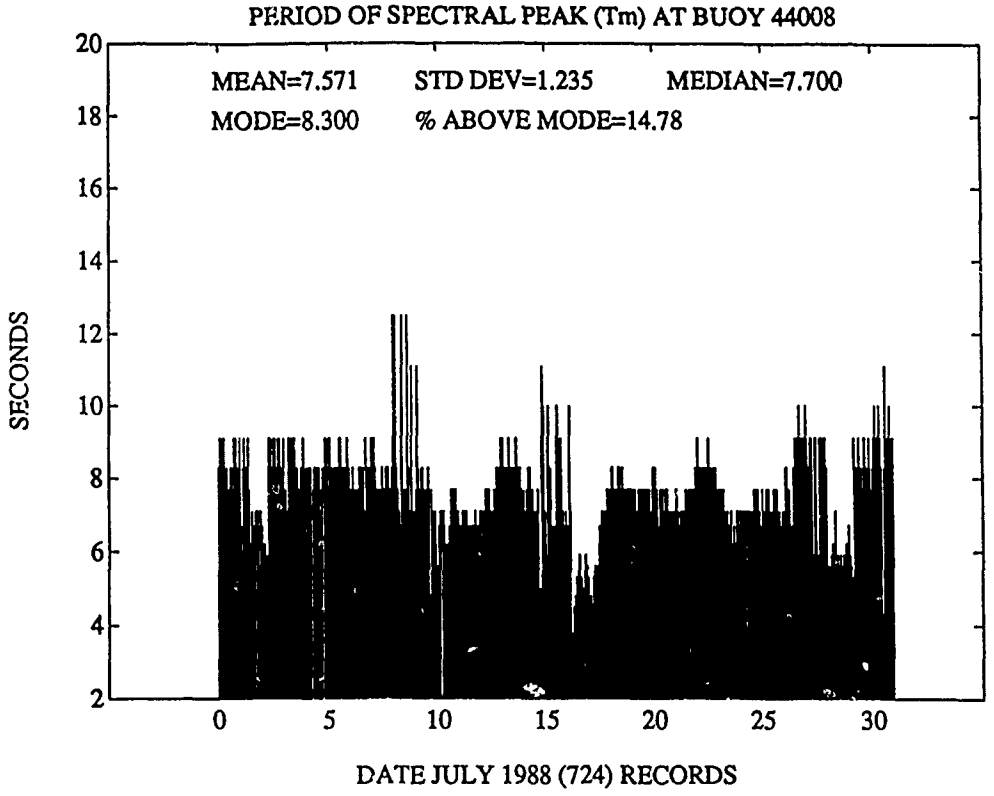


Figure 46: (continued) (c) Mean wave period time series, and (d) mean wave frequency distribution.



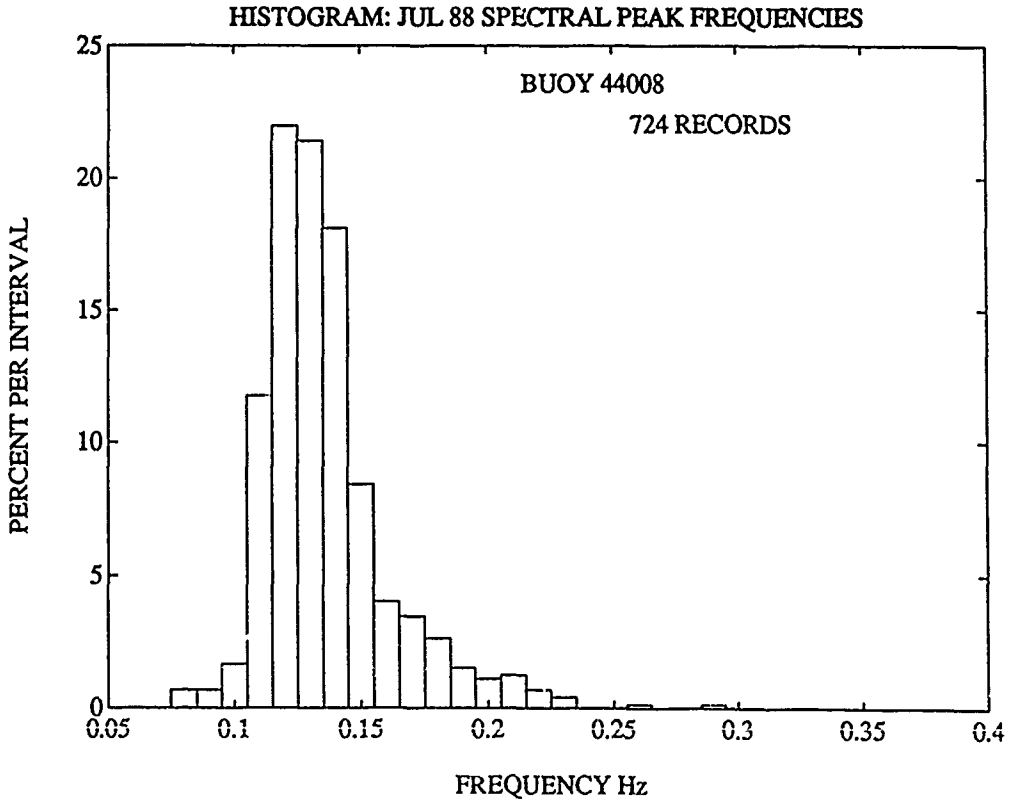
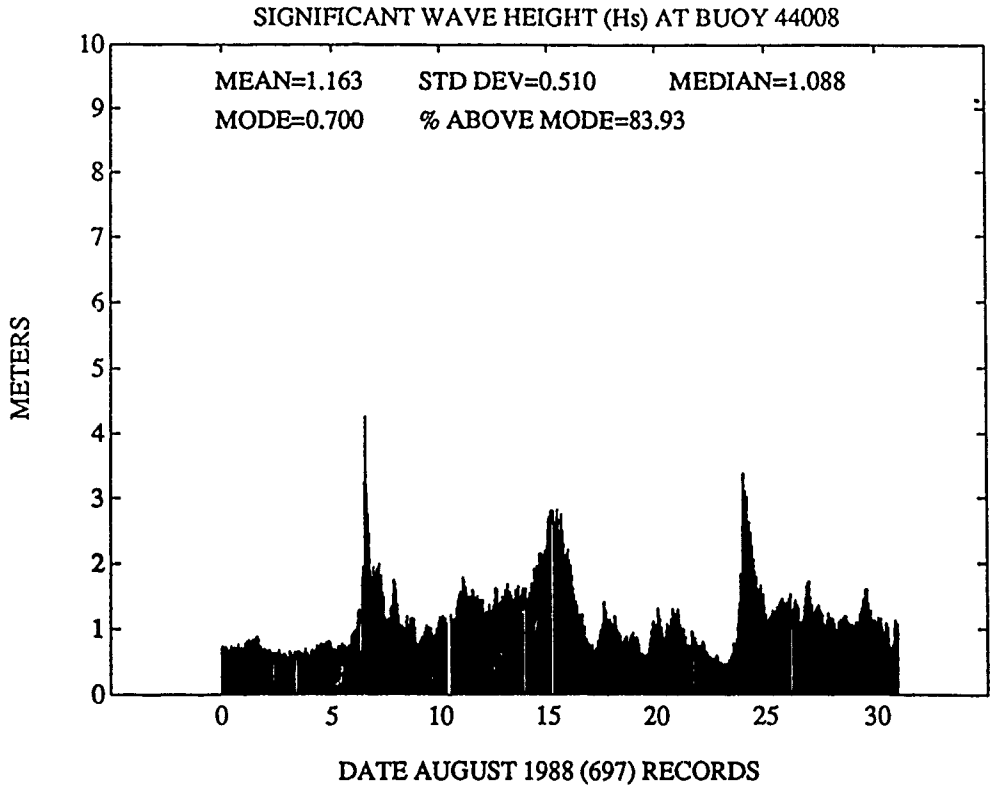


Figure 46: (continued) (e) Spectral peak period time series, and (f) spectral peak frequency distribution.



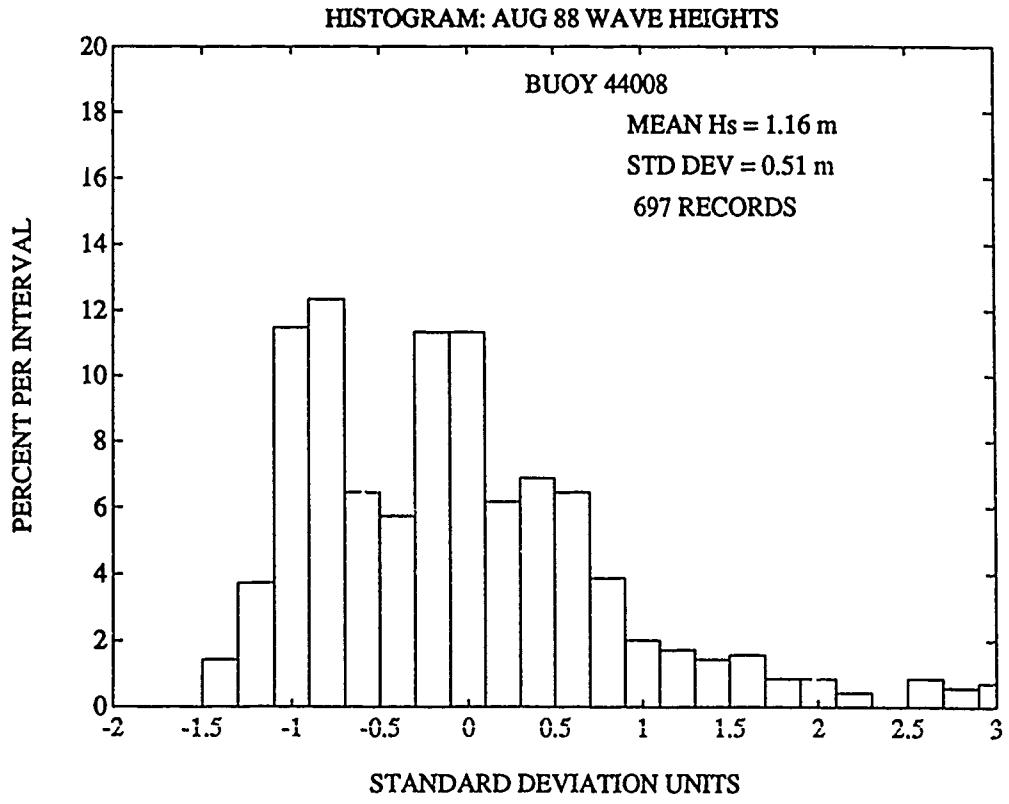
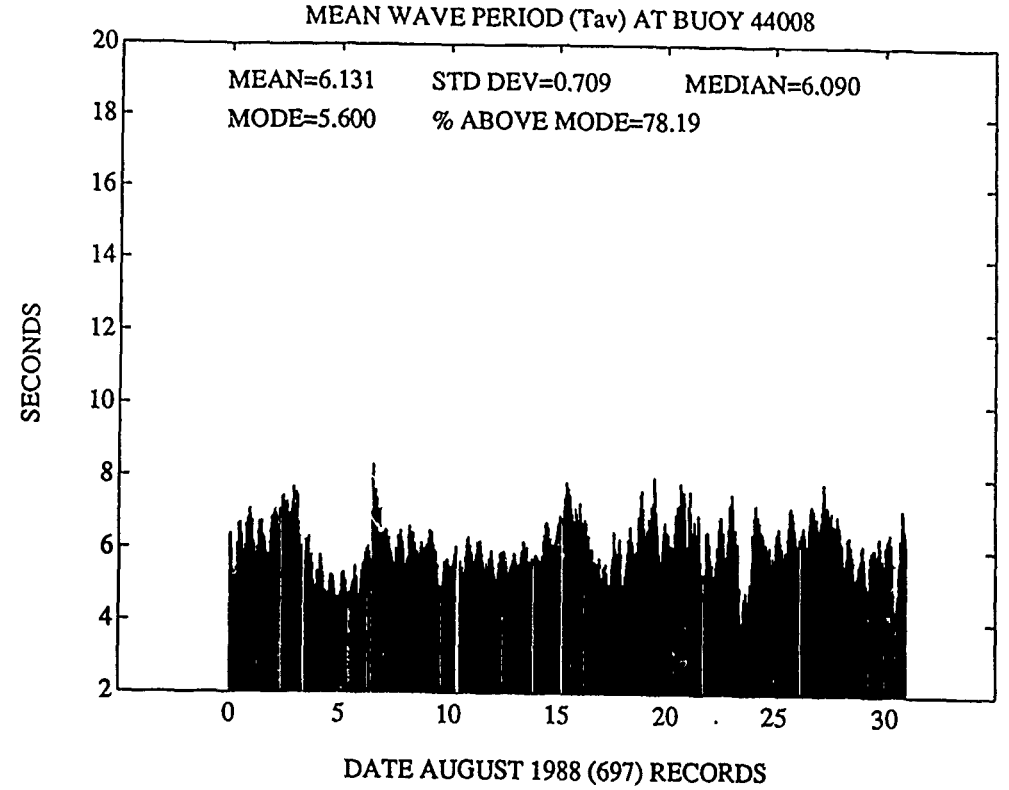


Figure 47: Wave height and period at Buoy 44008, August 1988. (a) Significant wave height time series, and (b) distribution.



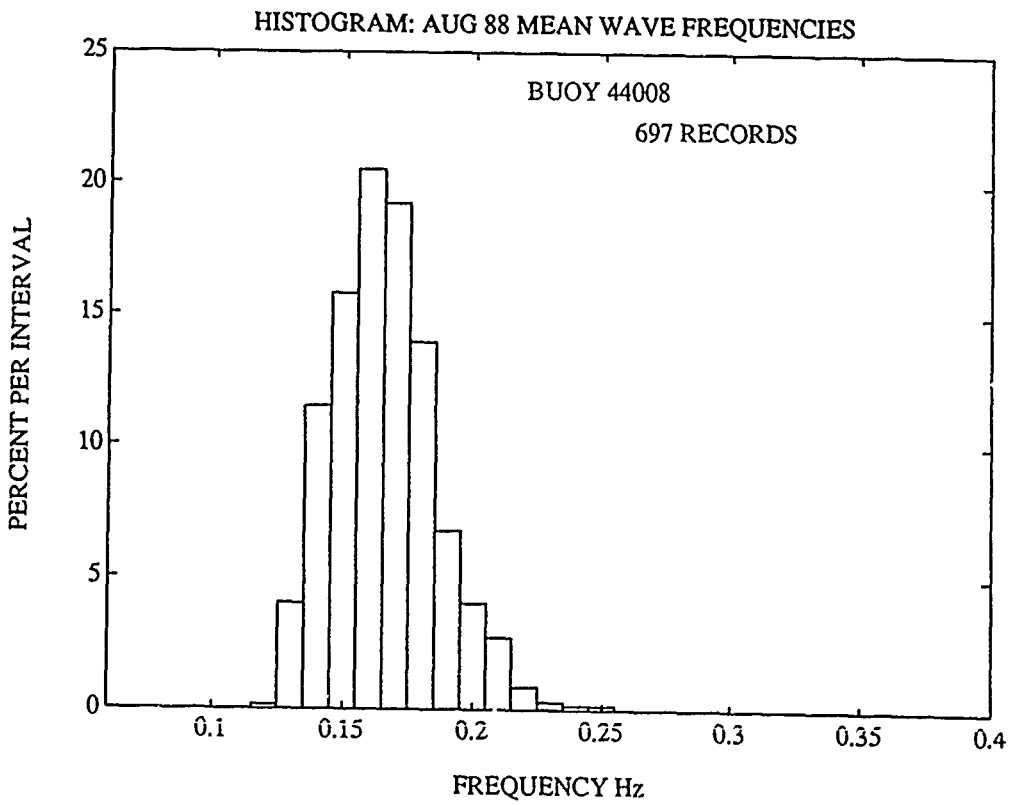
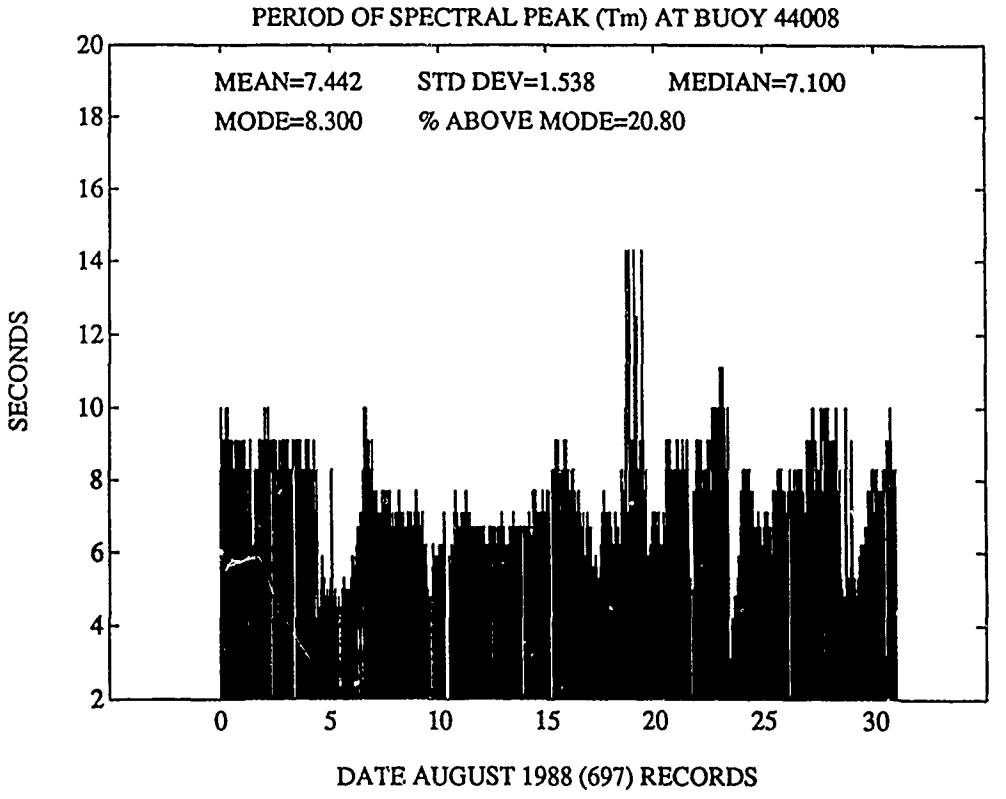


Figure 47: (continued) (c) Mean wave period time series, and (d) mean wave frequency distribution.



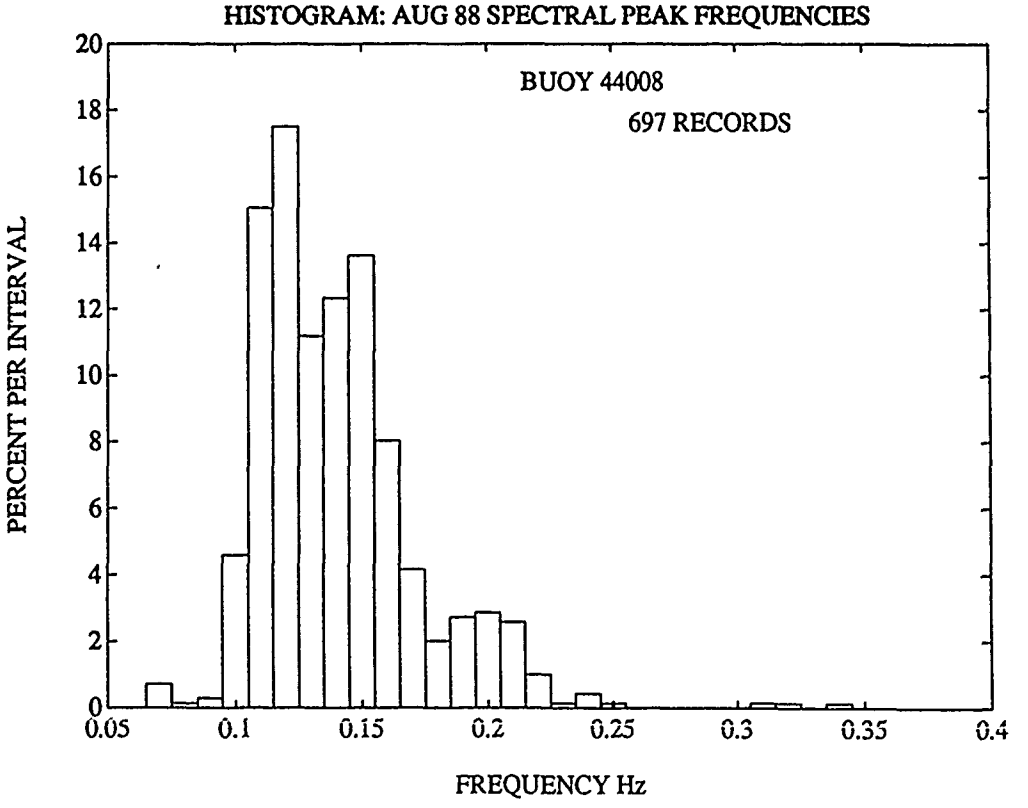
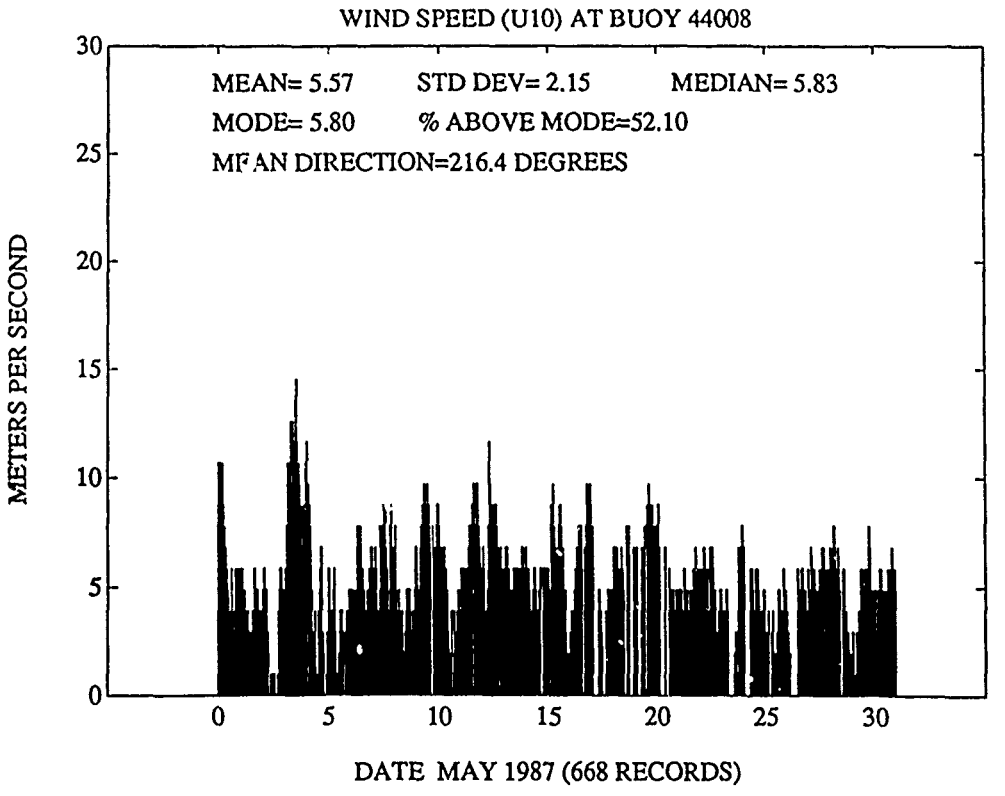


Figure 47: (continued) (e) Spectral peak period time series, and (f) spectral peak frequency distribution.



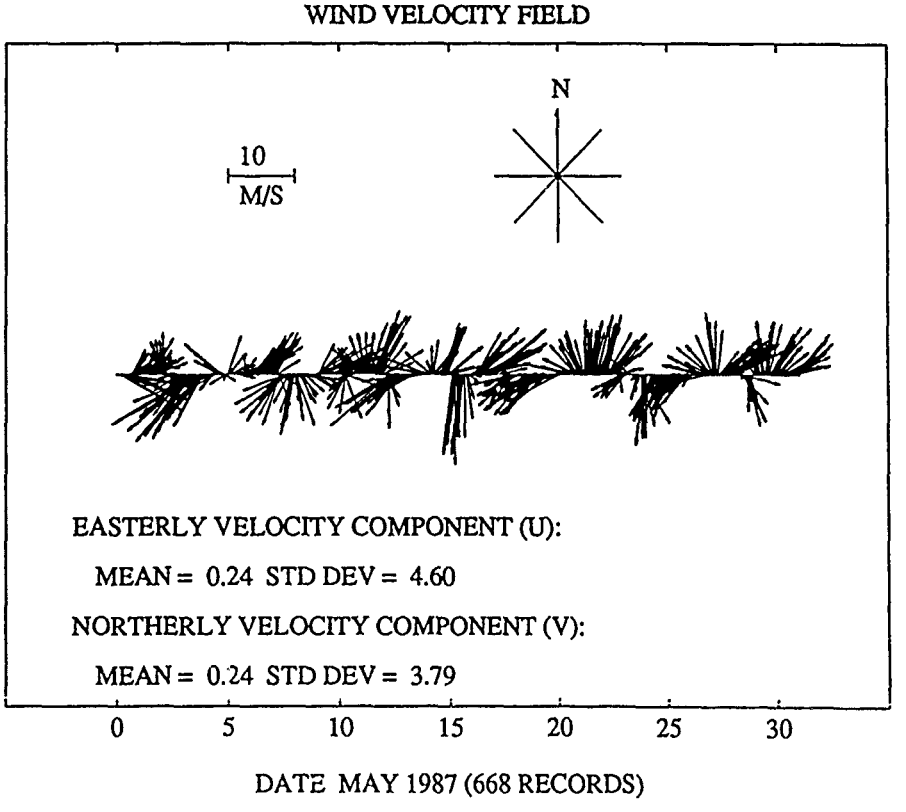
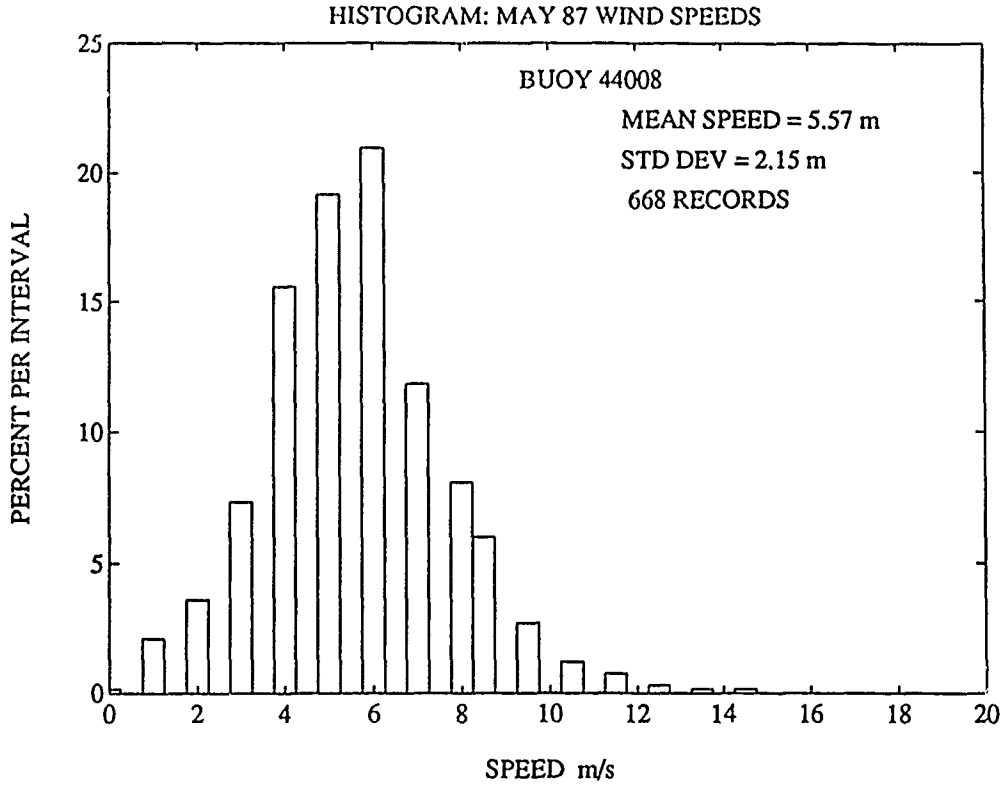


Figure 48: Wind speed and direction at Buoy 44008, May 1987. (a) Wind speed time series, and (b) wind velocity vector plot.



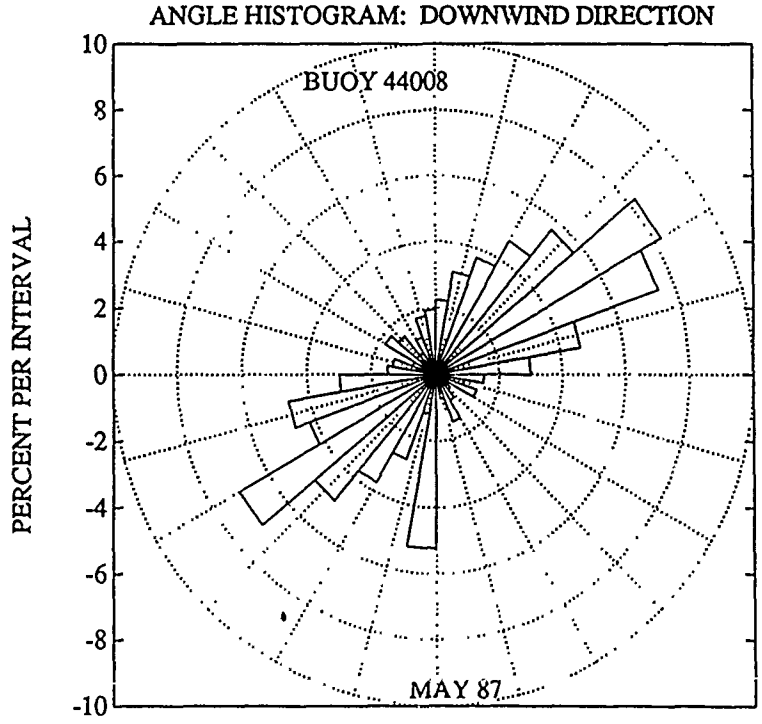
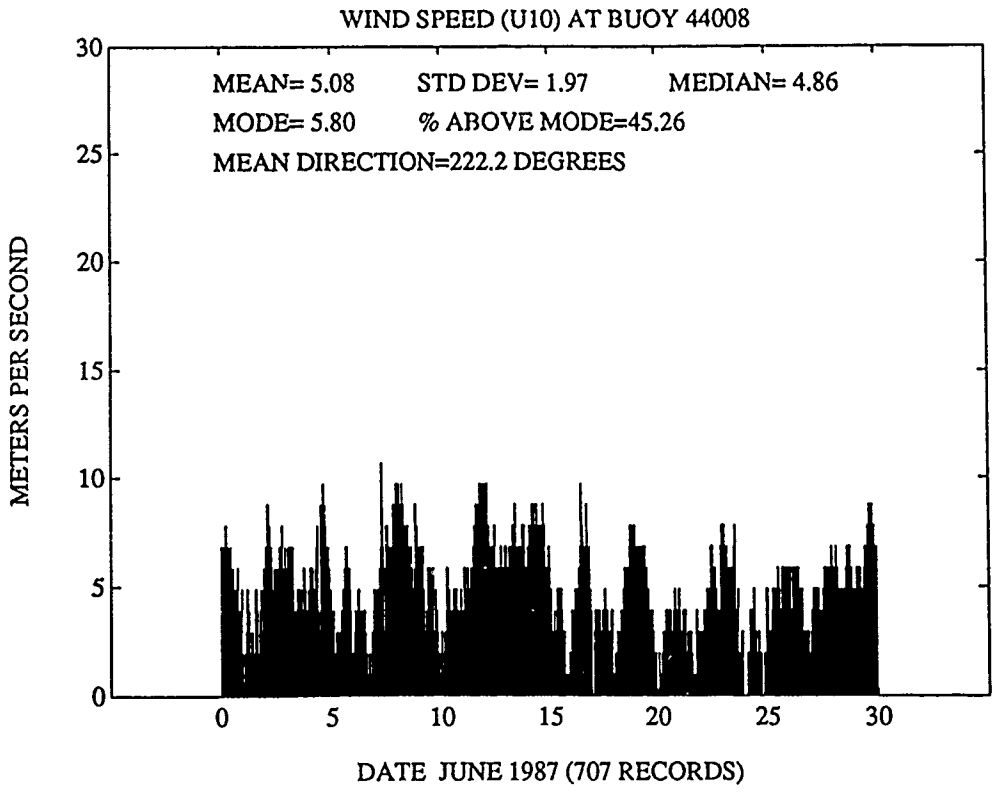


Figure 48: (continued) (c) Wind speed distribution, and (d) wind direction distribution.



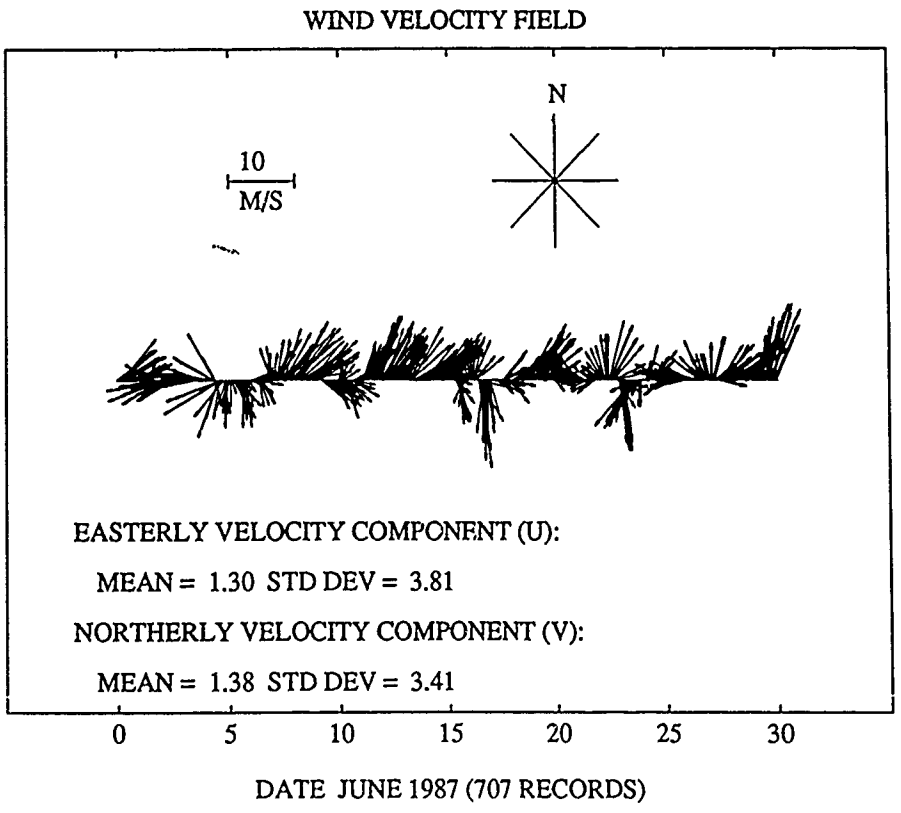
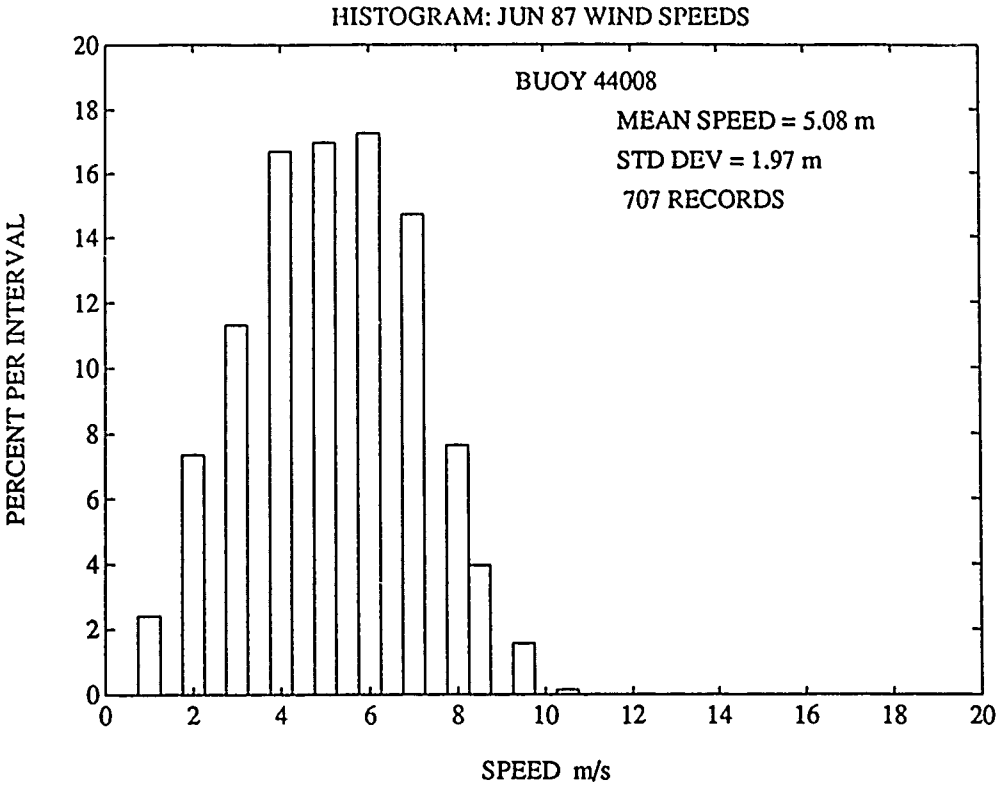


Figure 49: Wind speed and direction at Buoy 44008, June 1987. (a) Wind speed time series, and (b) wind velocity vector plot.



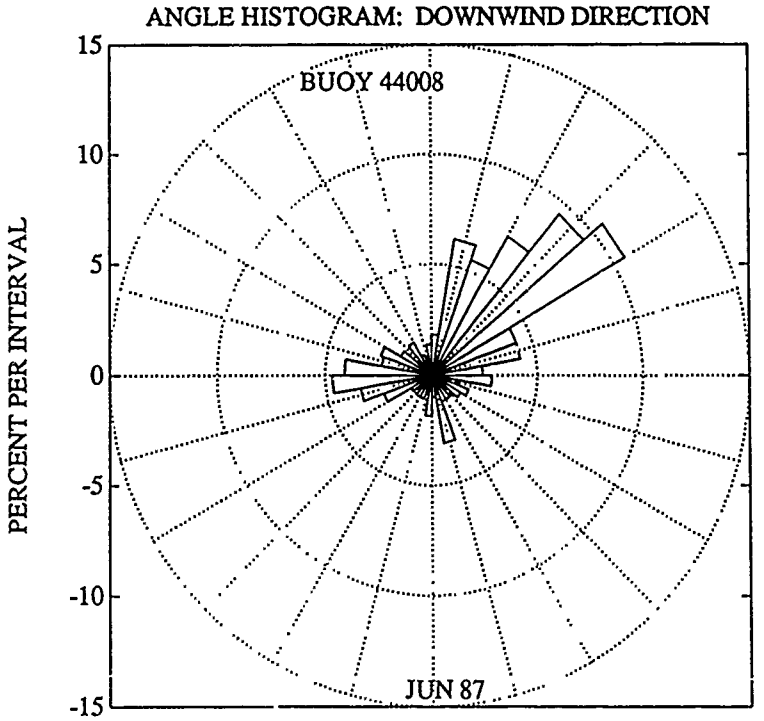
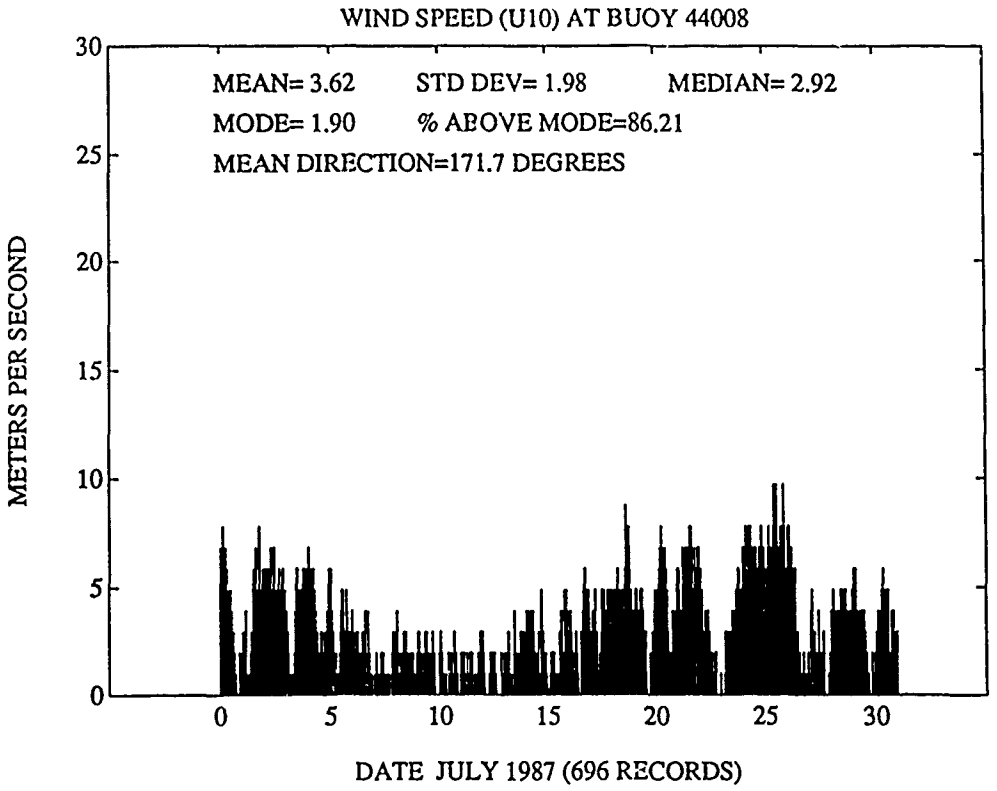


Figure 49: (continued) (c) Wind speed distribution, and (d) wind direction distribution.



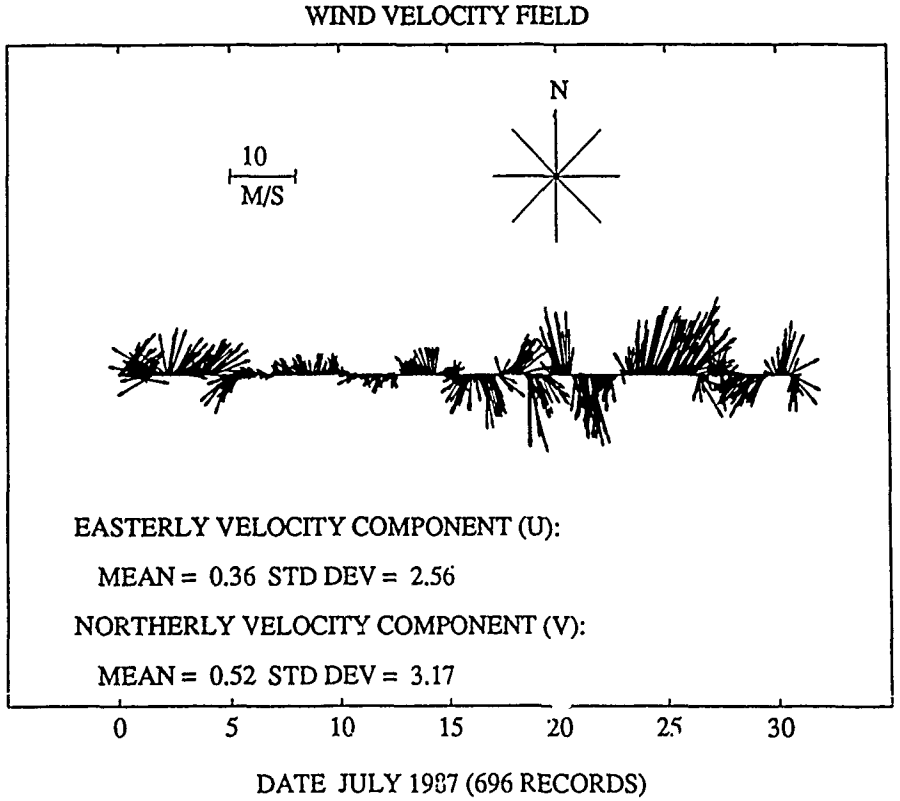
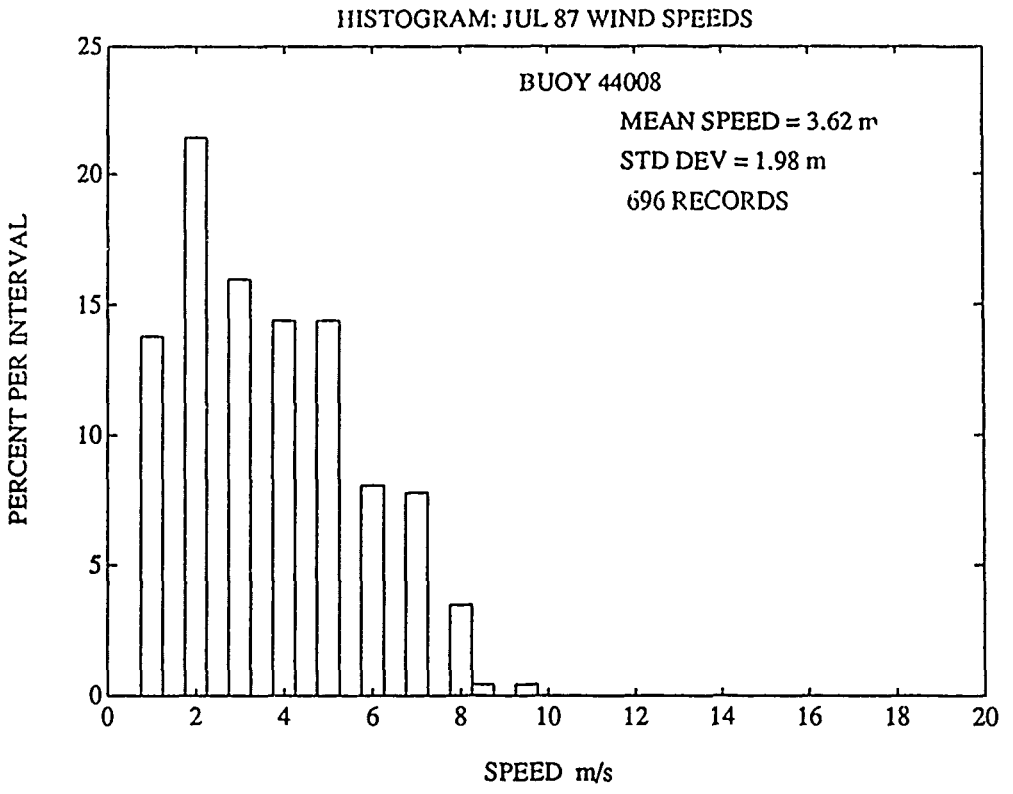


Figure 50: Wind speed and direction at Buoy 44008, July 1987. (a) Wind speed time series, and (b) wind velocity vector plot.



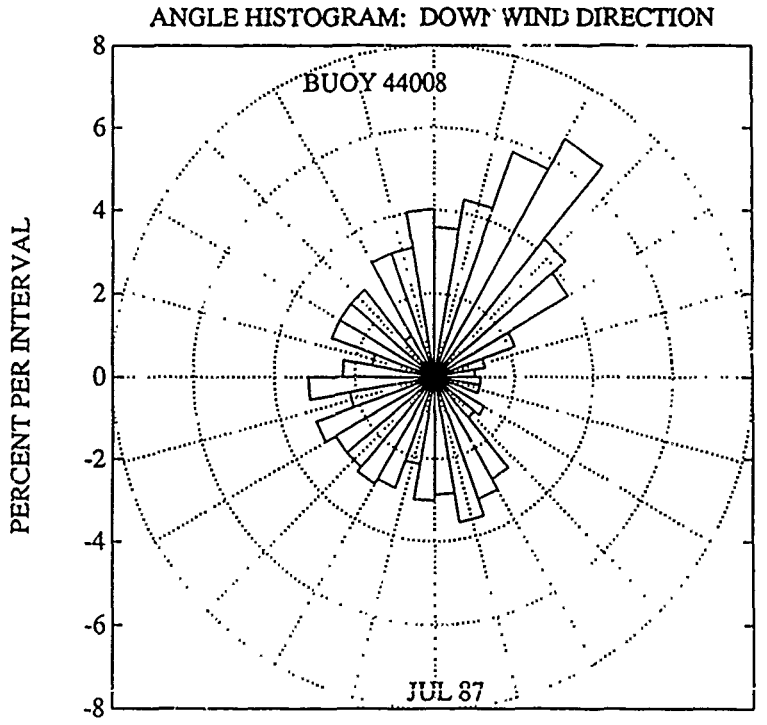
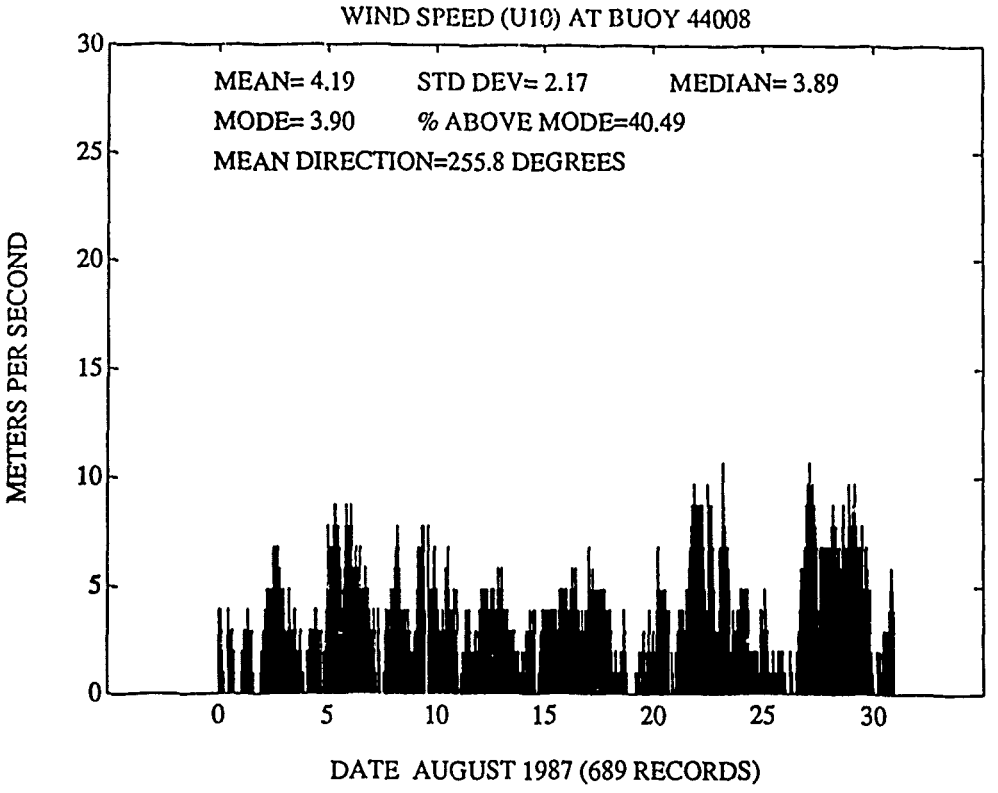


Figure 50: (continued) (c) Wind speed distribution, and (d) wind direction distribution.



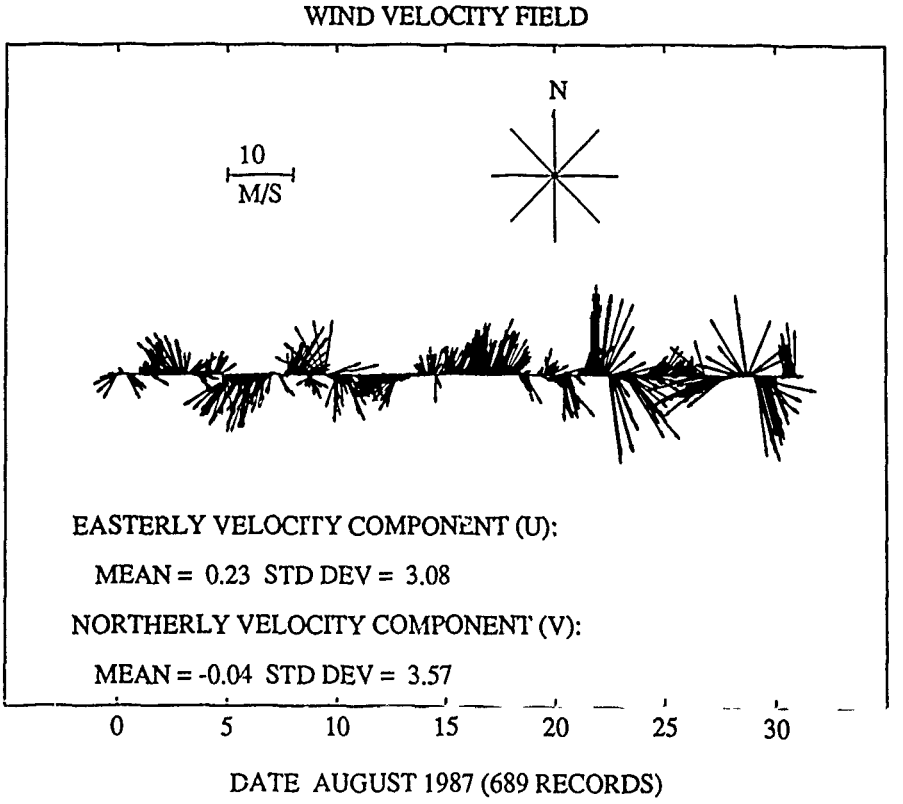
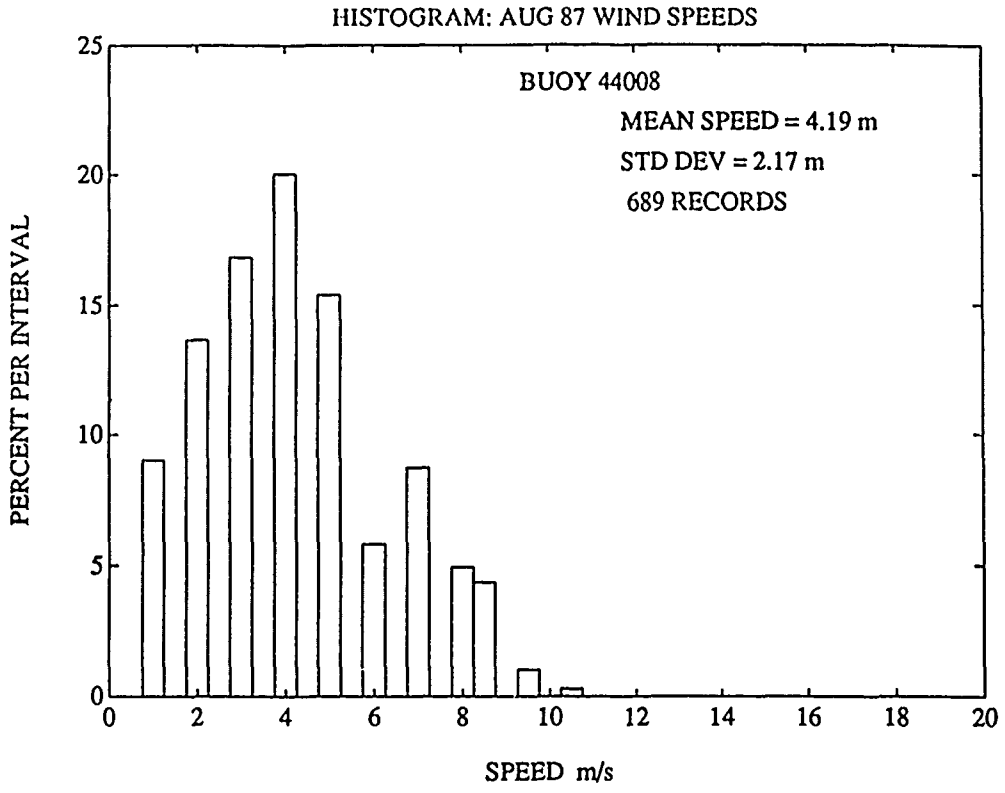


Figure 51: Wind speed and direction at Buoy 44008, August 1987. (a) Wind speed time series, and (b) wind velocity vector plot.



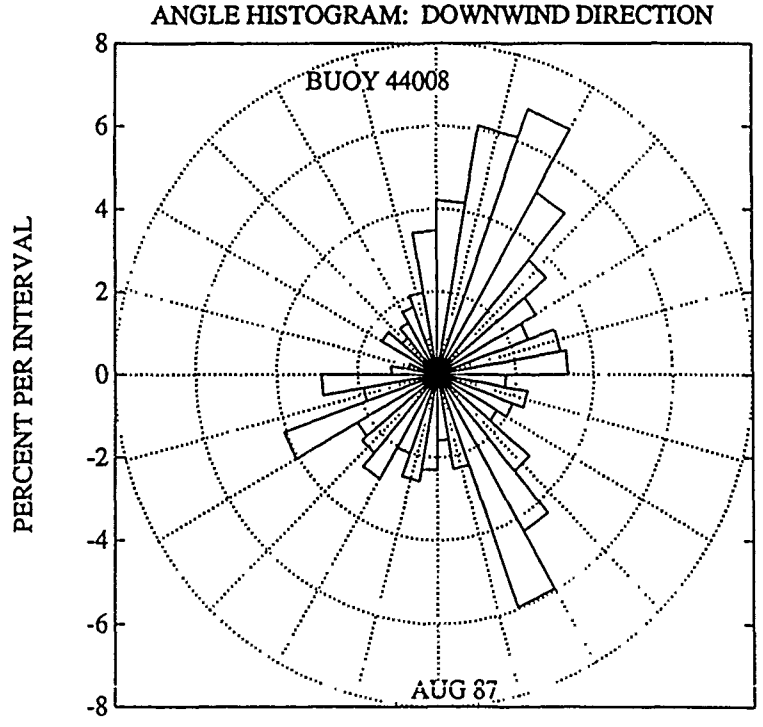
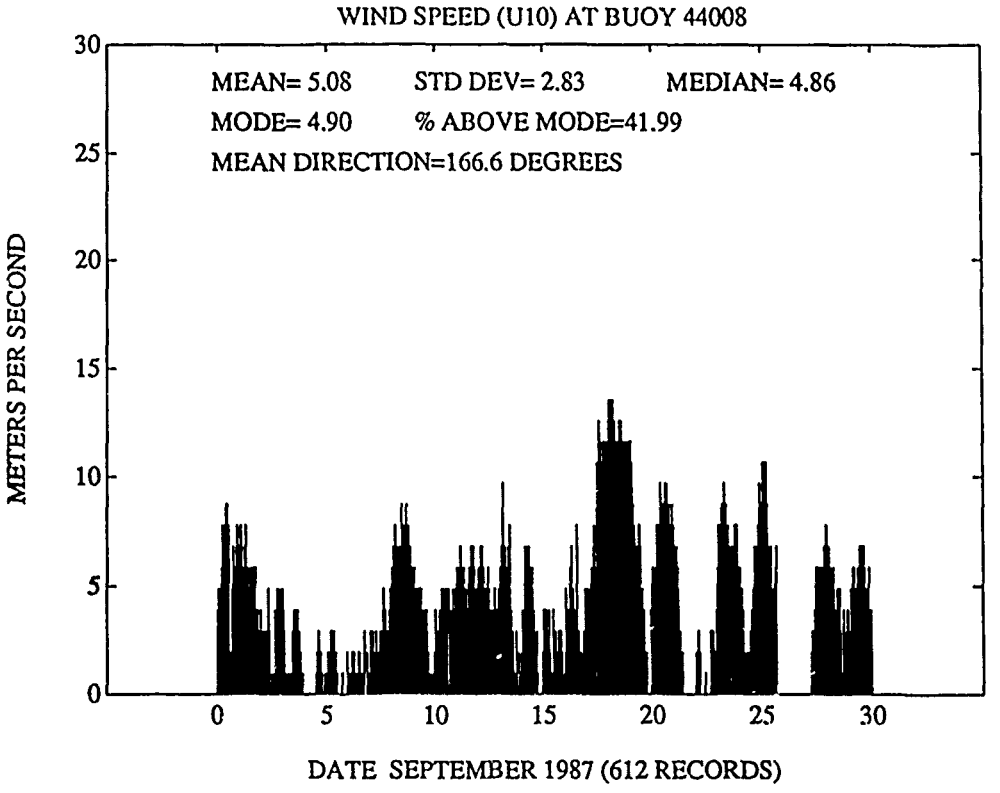


Figure 51: (continued) (c) Wind speed distribution, and (d) wind direction distribution.



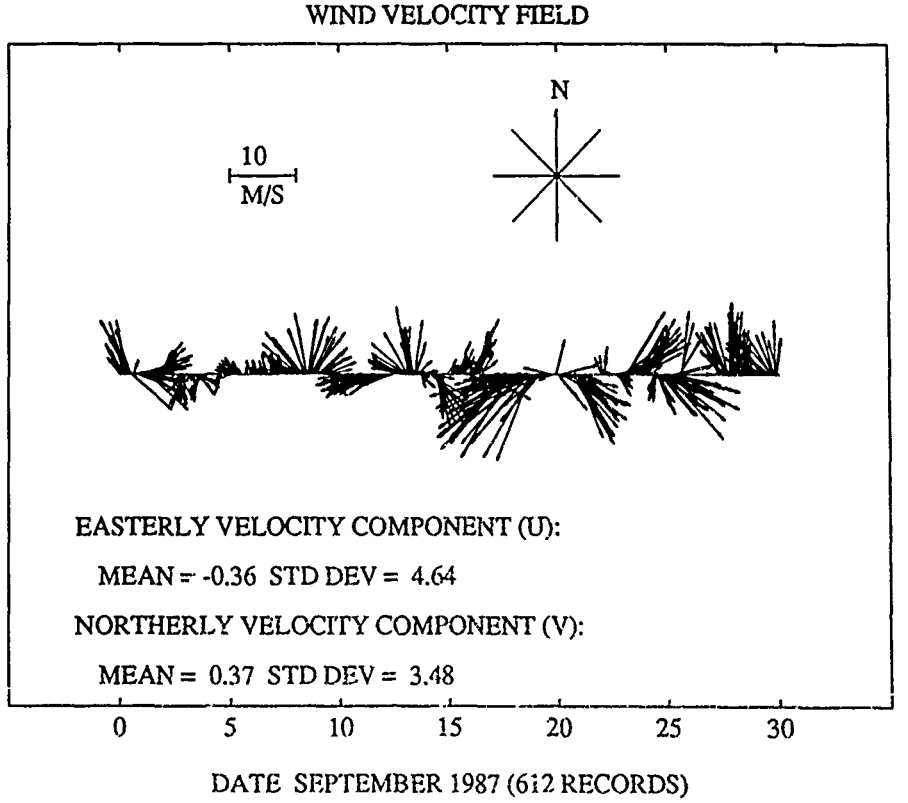
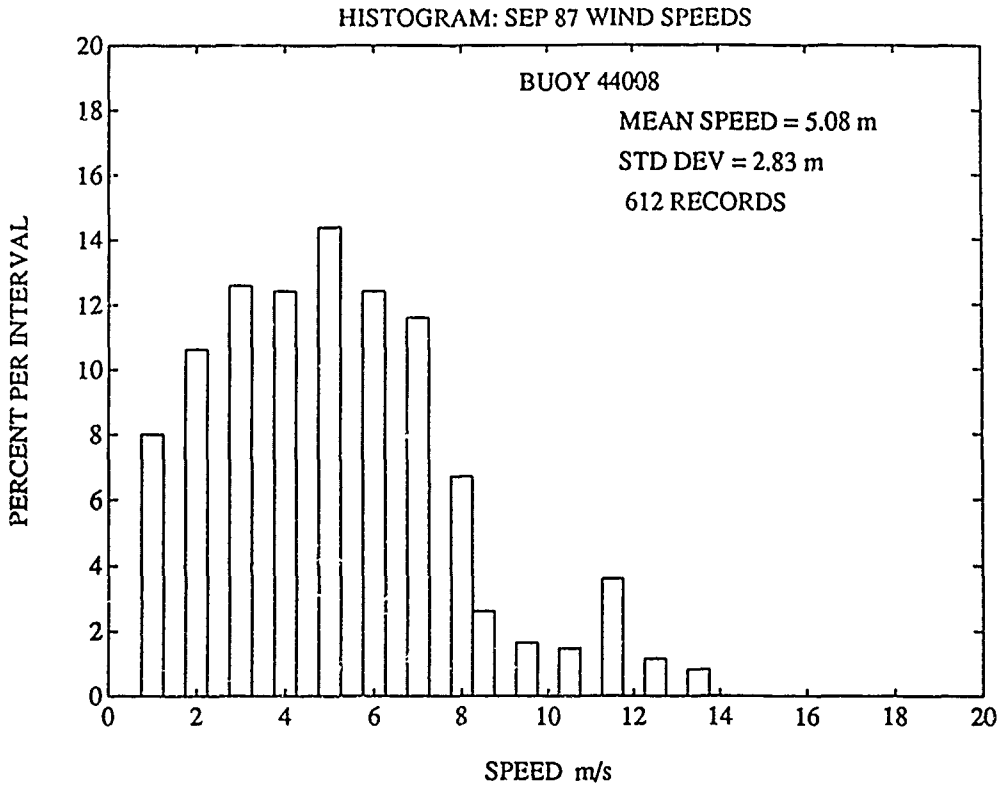


Figure 52: Wind speed and direction at Buoy 44008, September 1987. (a) Wind speed time series, and (b) wind velocity vector plot.



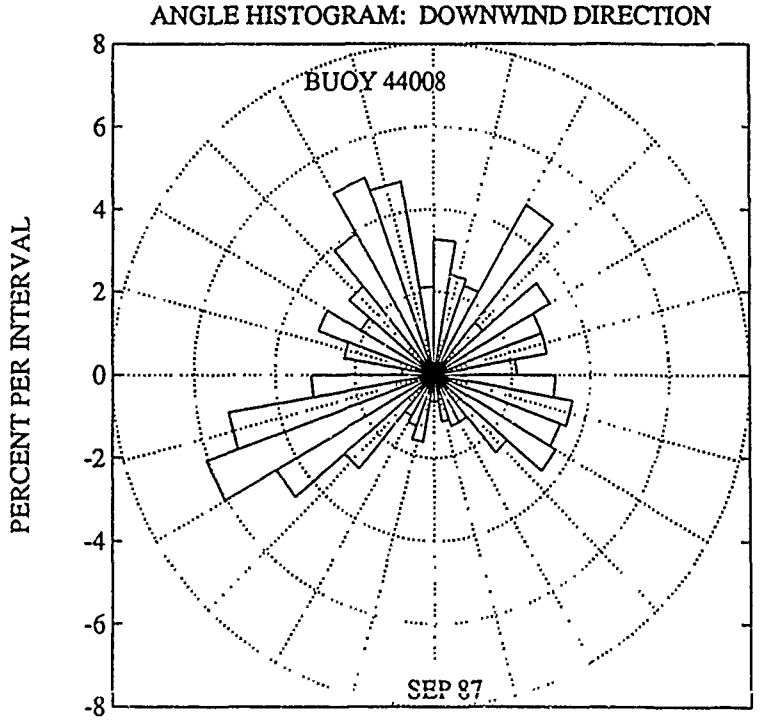
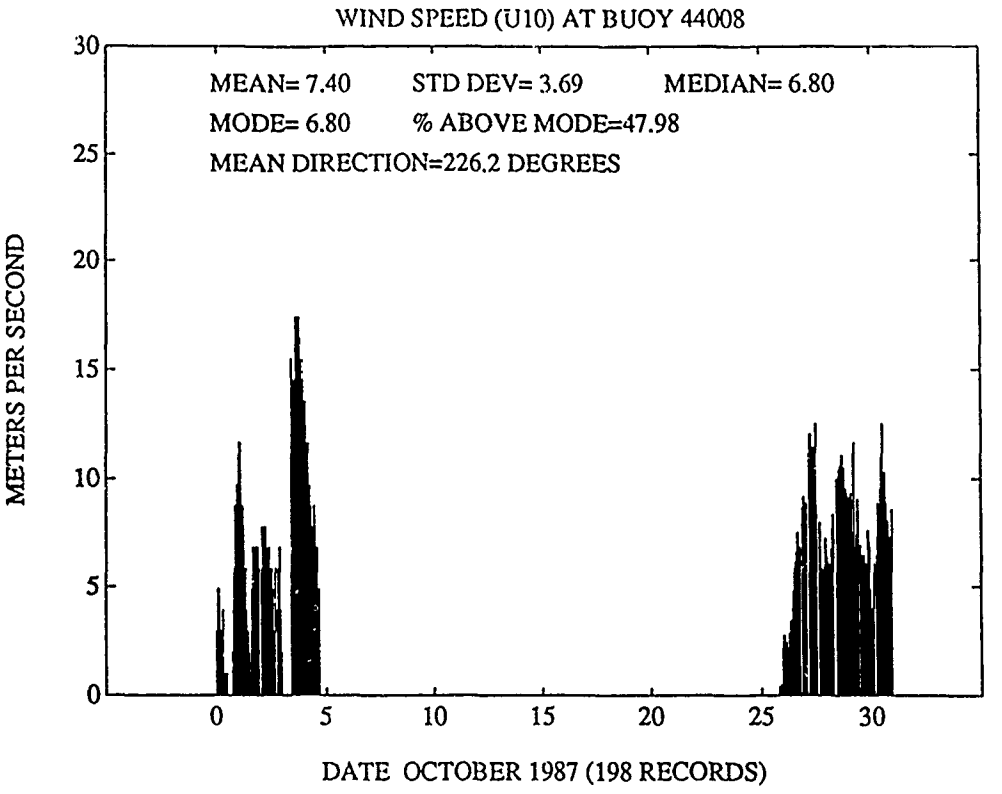


Figure 52: (continued) (c) Wind speed distribution, and (d) wind direction distribution.



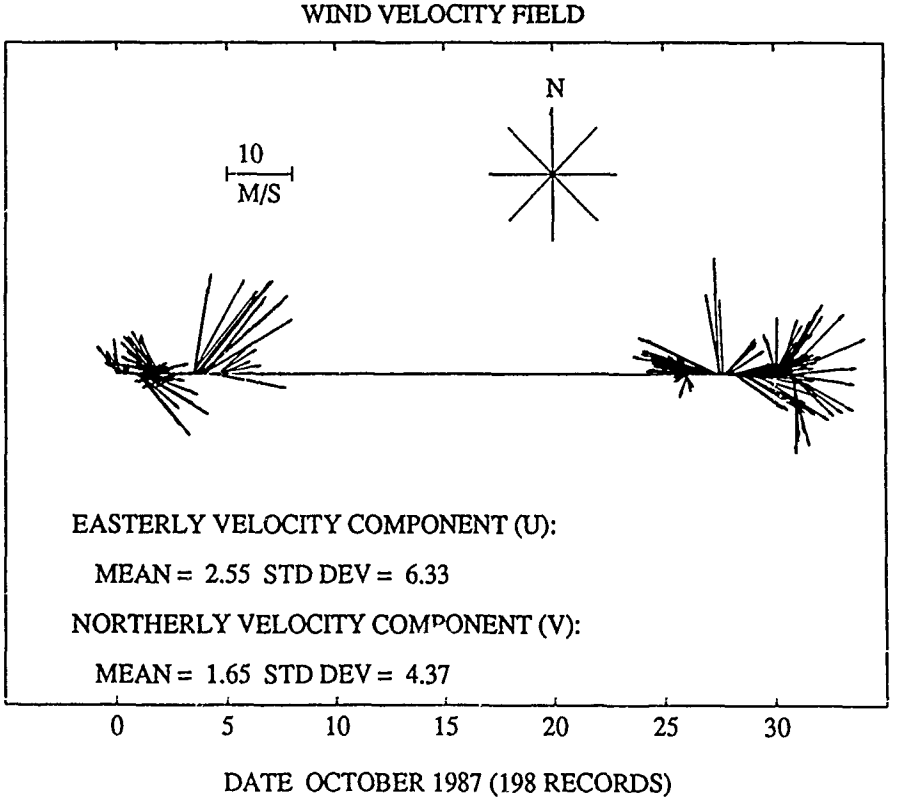
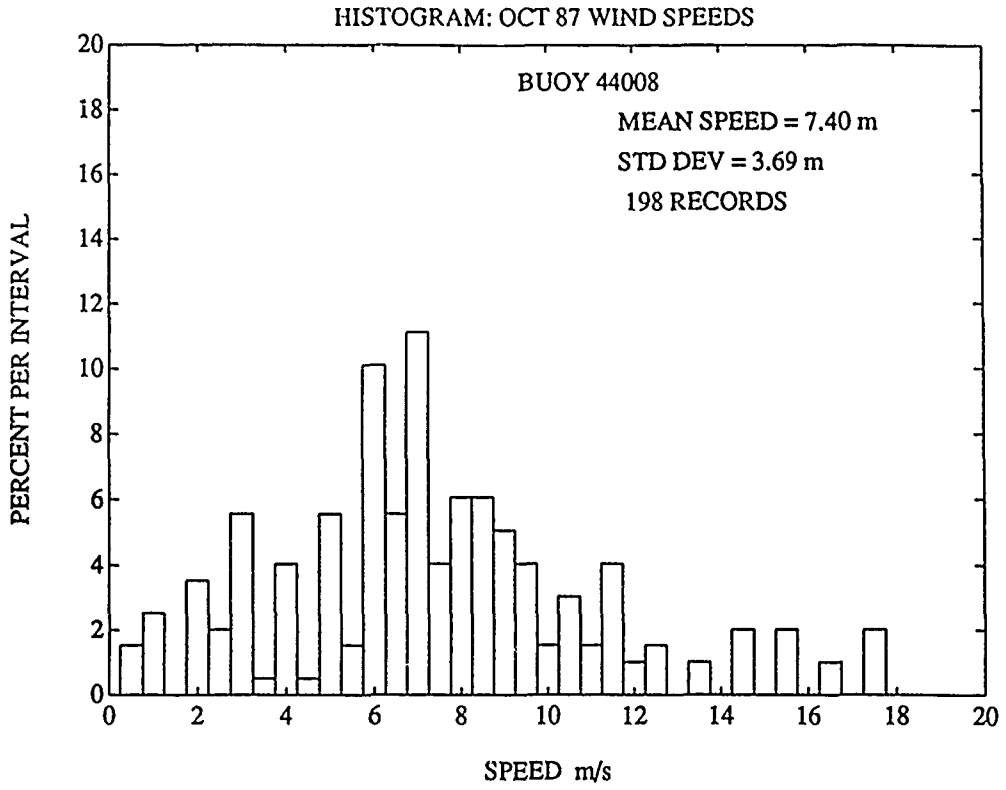


Figure 53: Wind speed and direction at Buoy 44008, October 1987. (a) Wind speed time series, and (b) wind velocity vector plot.



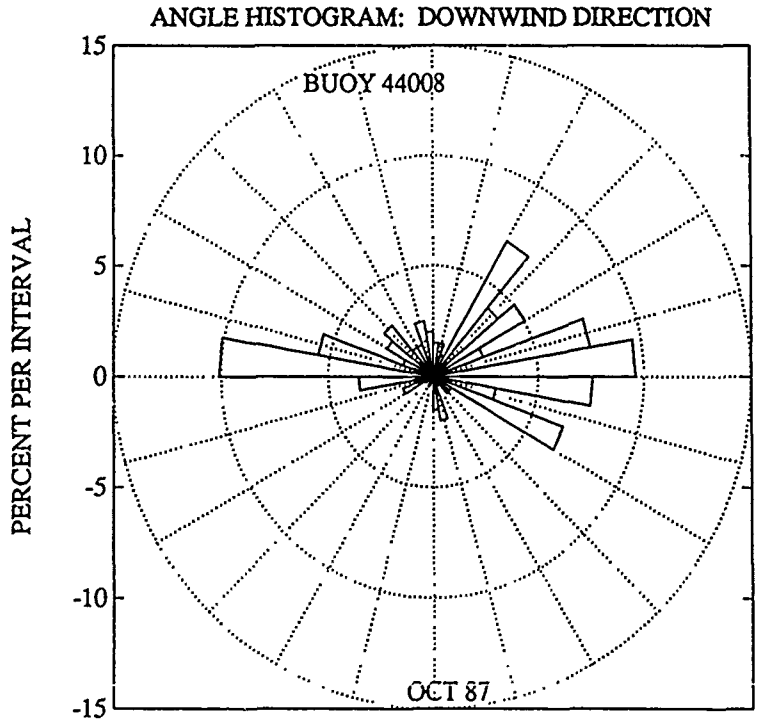
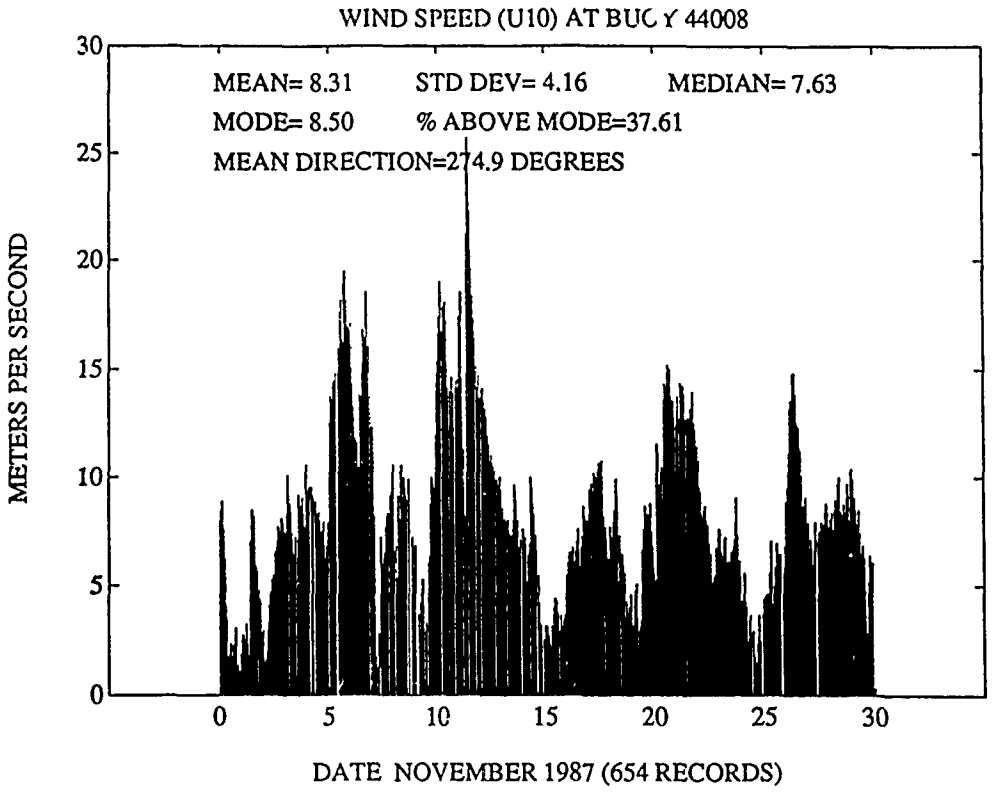


Figure 53: (continued) (c) Wind speed distribution, and (d) wind direction distribution.



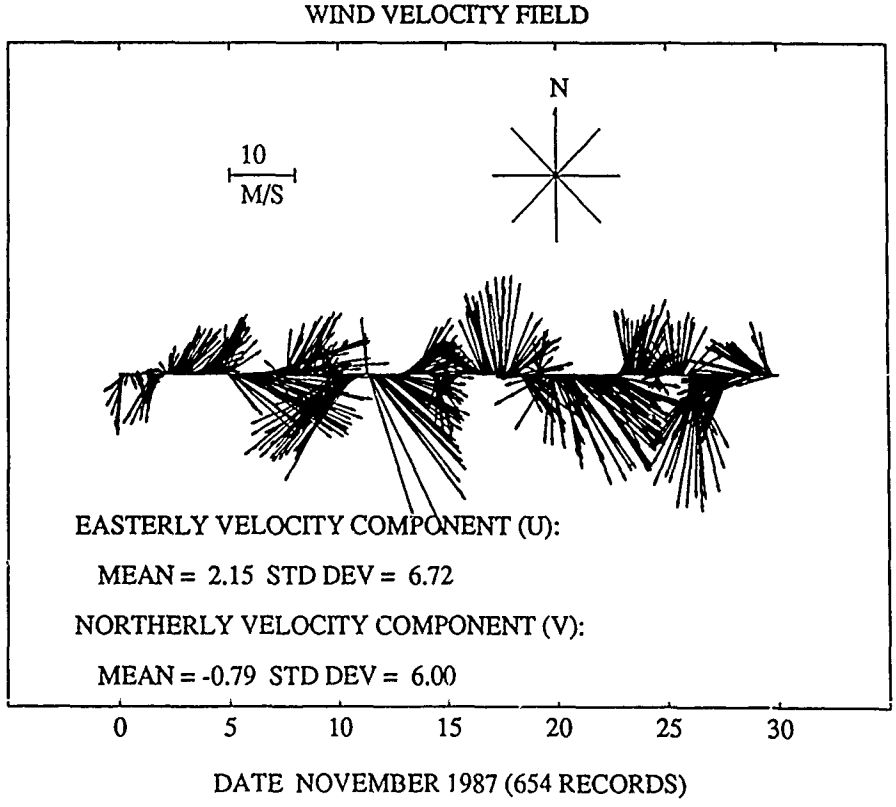
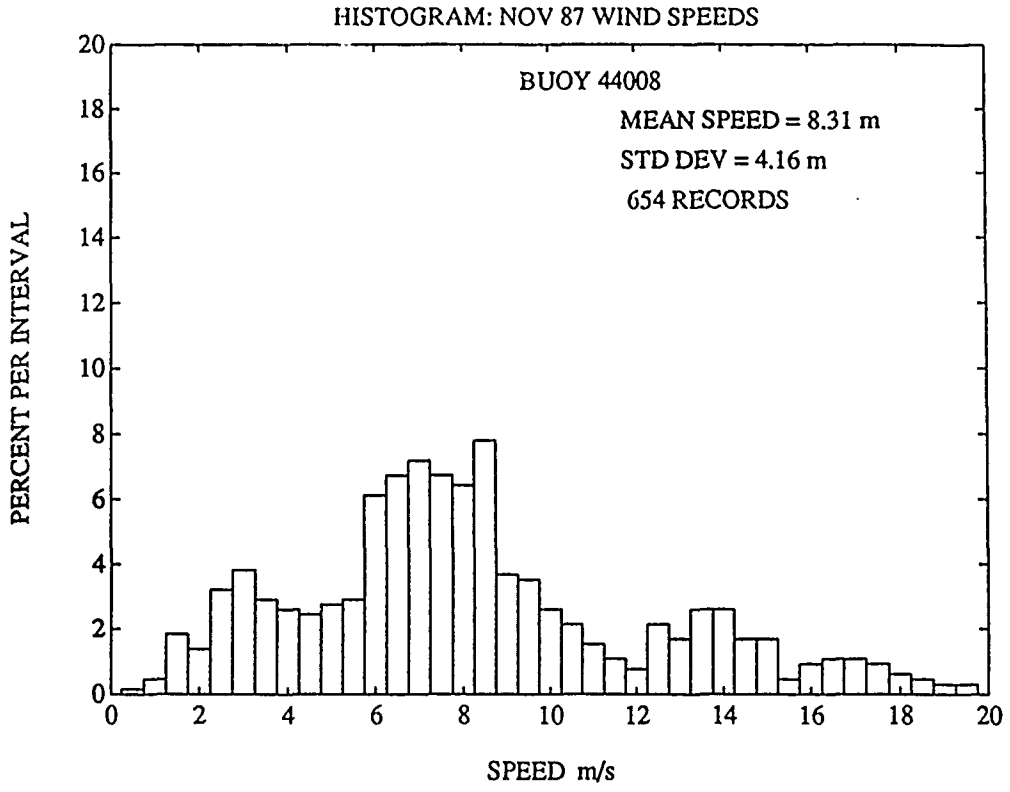


Figure 54: Wind speed and direction at Buoy 44008, November 1987. (a) Wind speed time series, and (b) wind velocity vector plot.



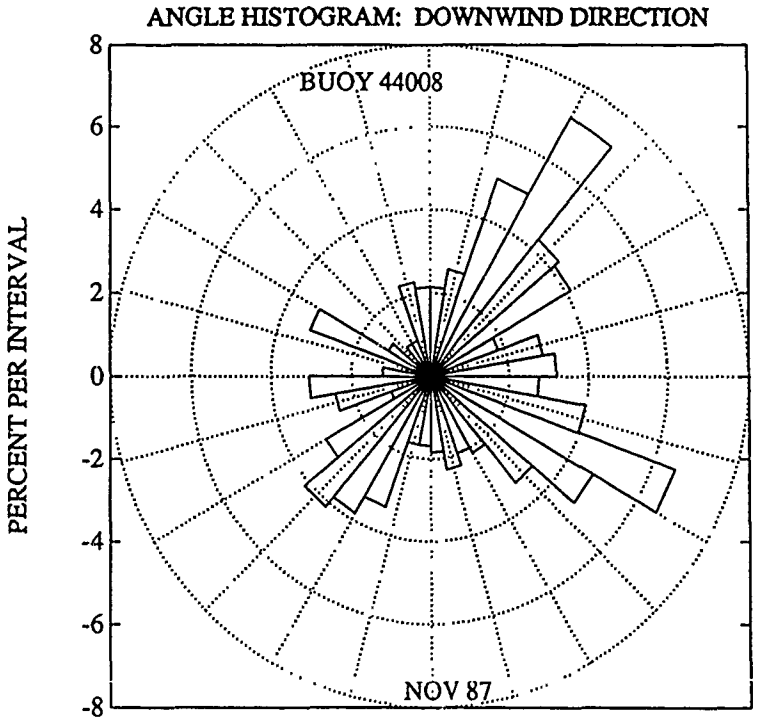
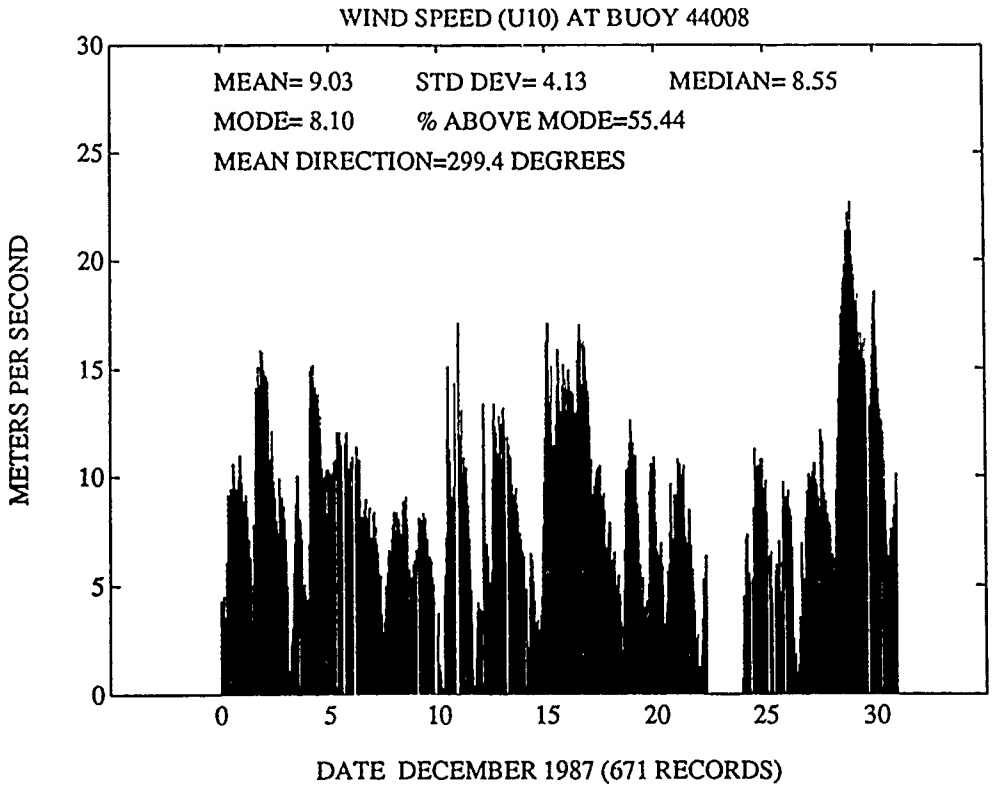


Figure 54: (continued) (c) Wind speed distribution, and (d) wind direction distribution.



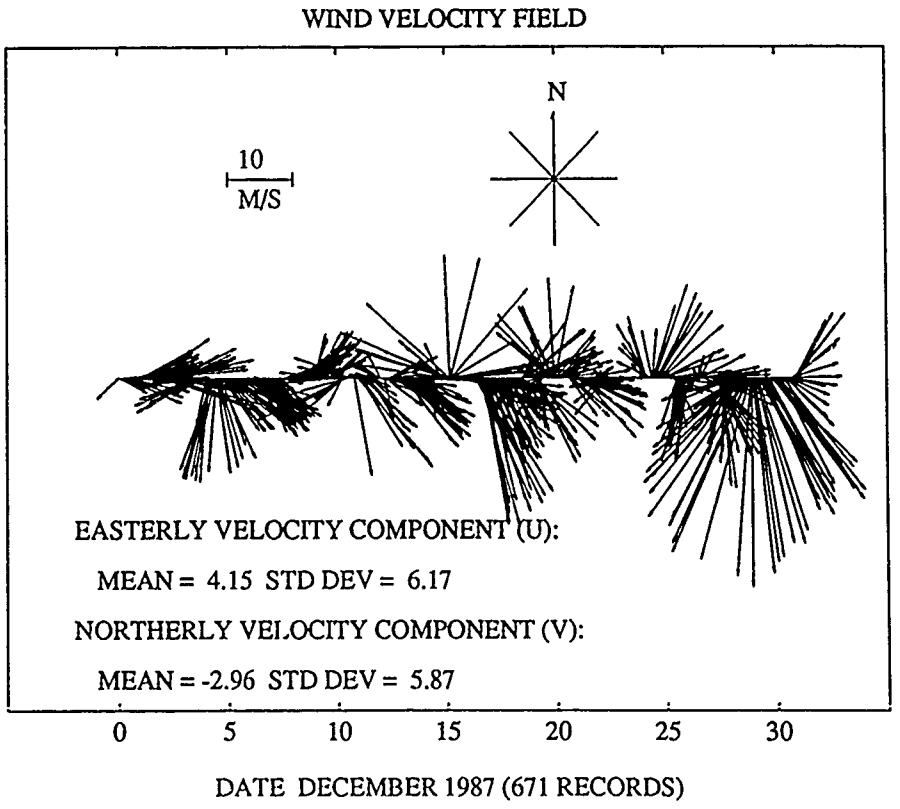
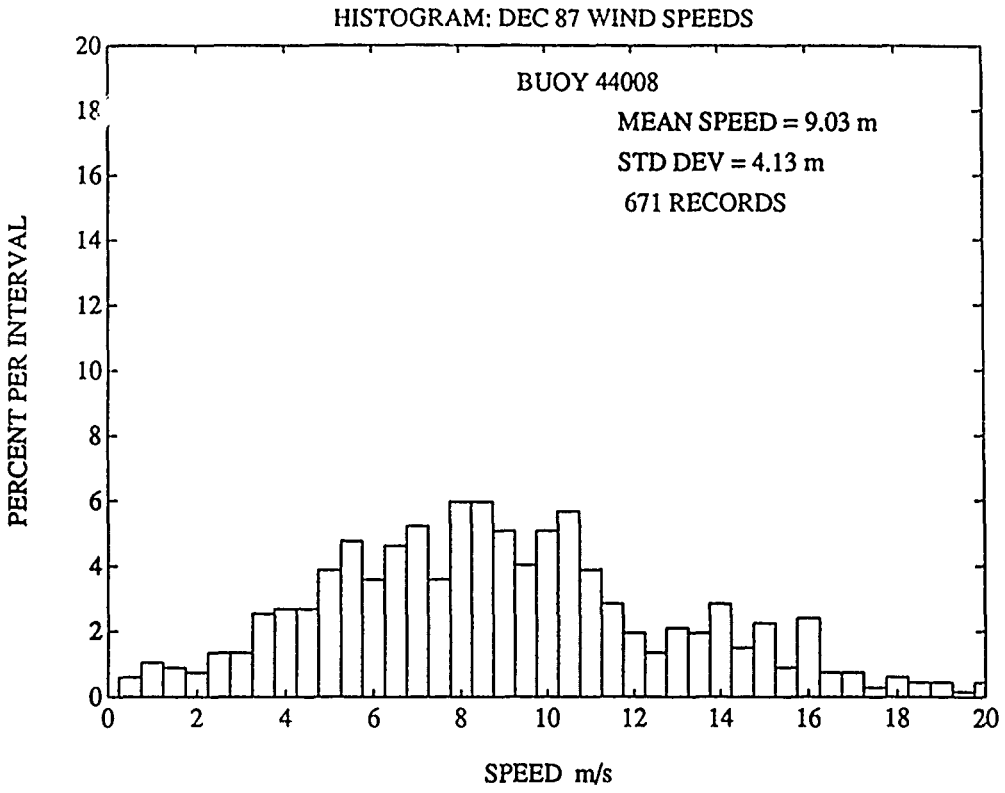


Figure 55: Wind speed and direction at Buoy 44008, December 1987. (a) Wind speed time series, and (b) wind velocity vector plot.



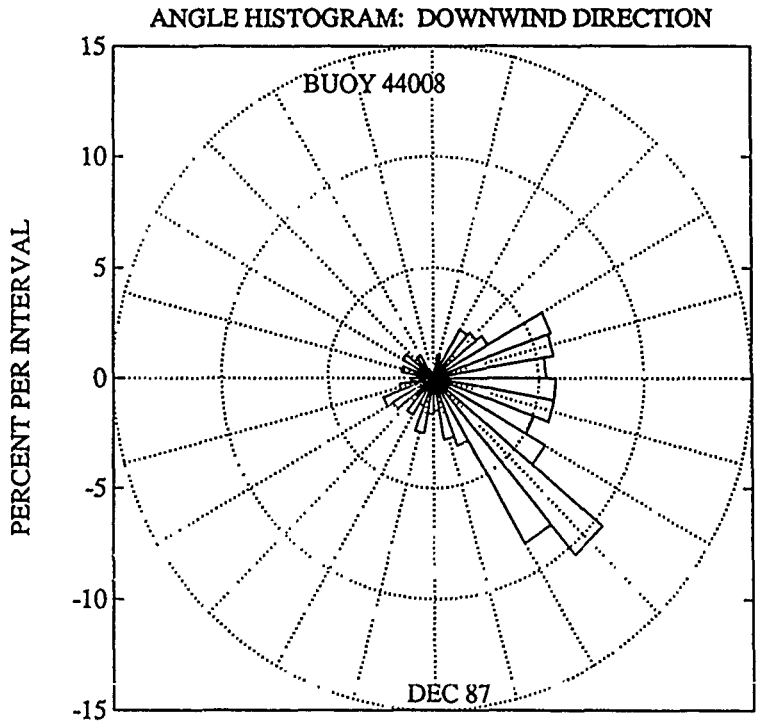
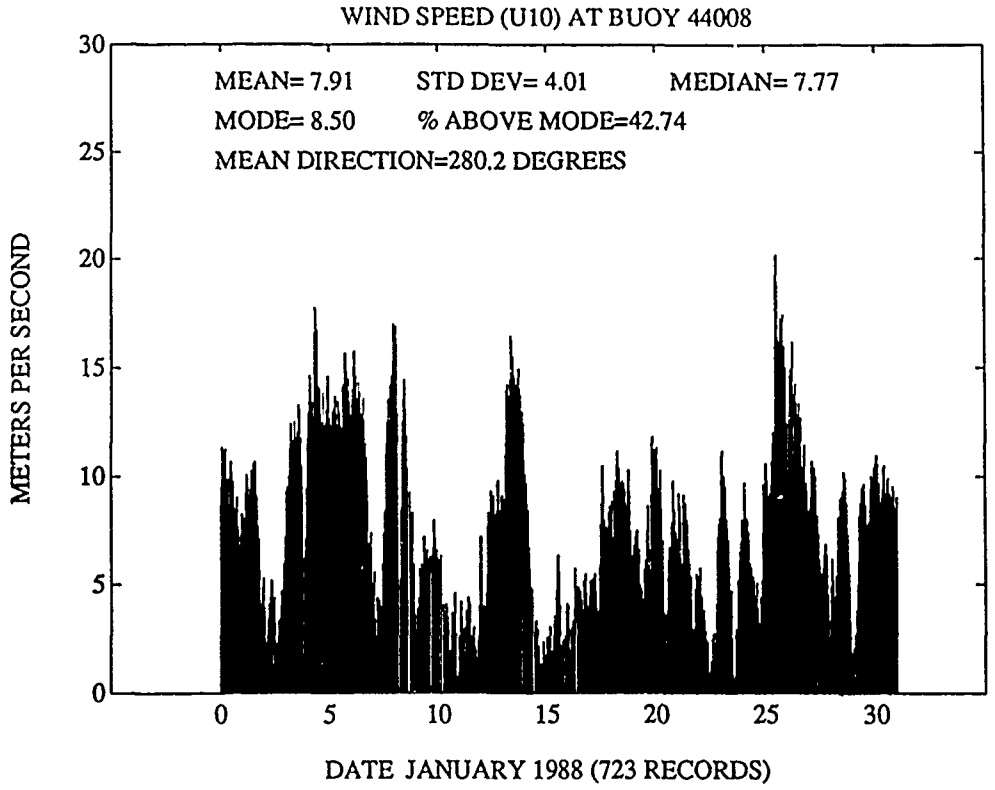


Figure 55: (continued) (c) Wind speed distribution, and (d) wind direction distribution.



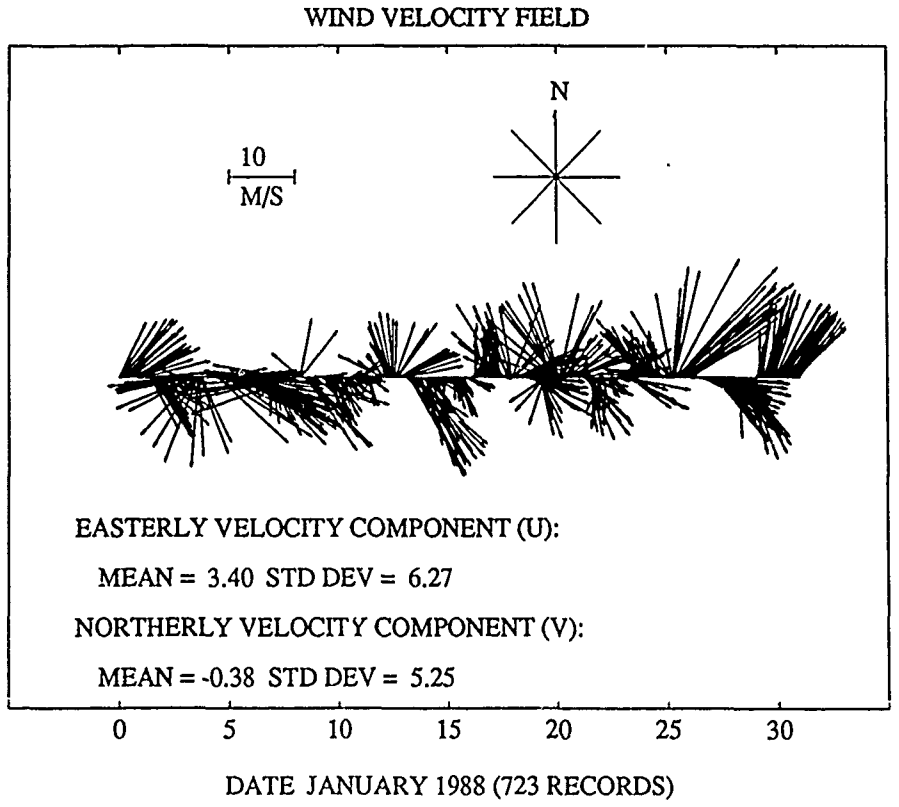
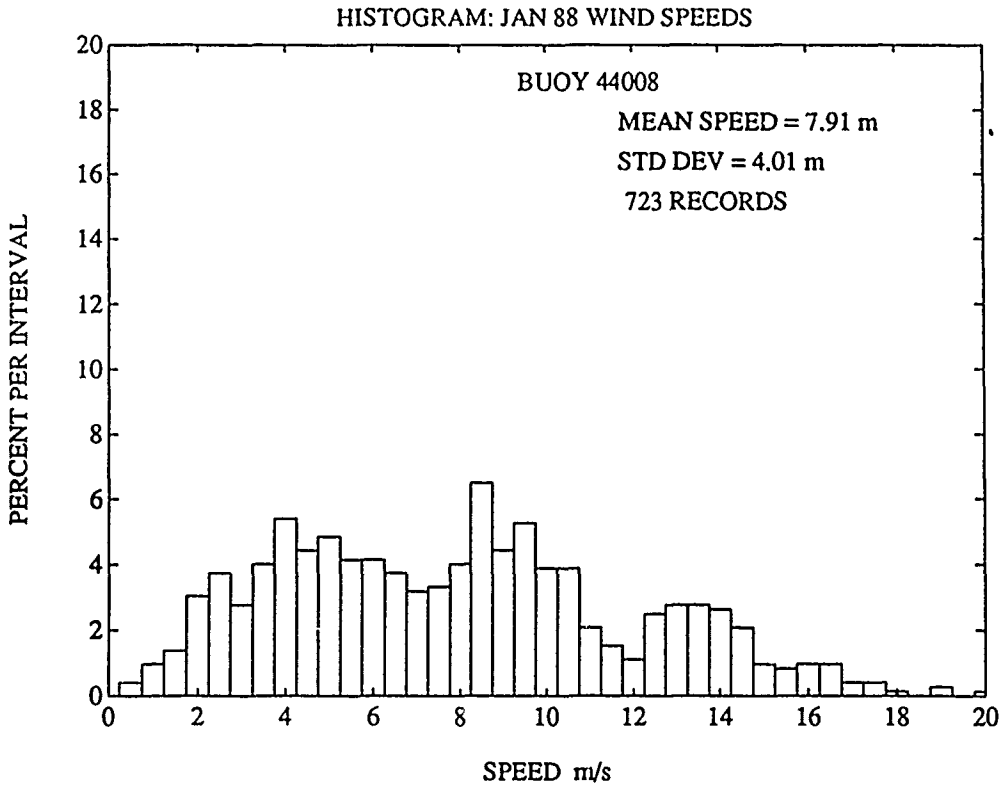


Figure 56: Wind speed and direction at Buoy 44008, January 1988. (a) Wind speed time series, and (b) wind velocity vector plot.



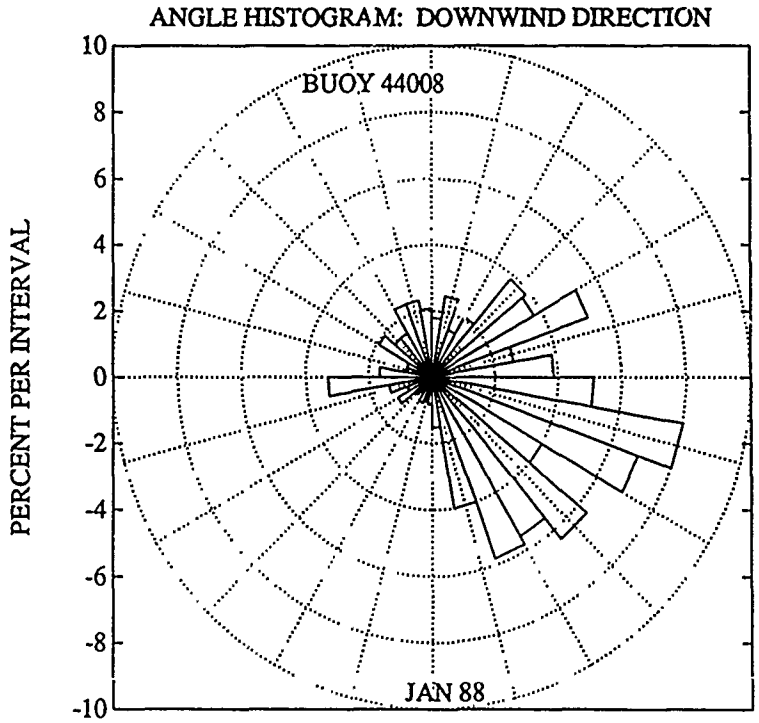
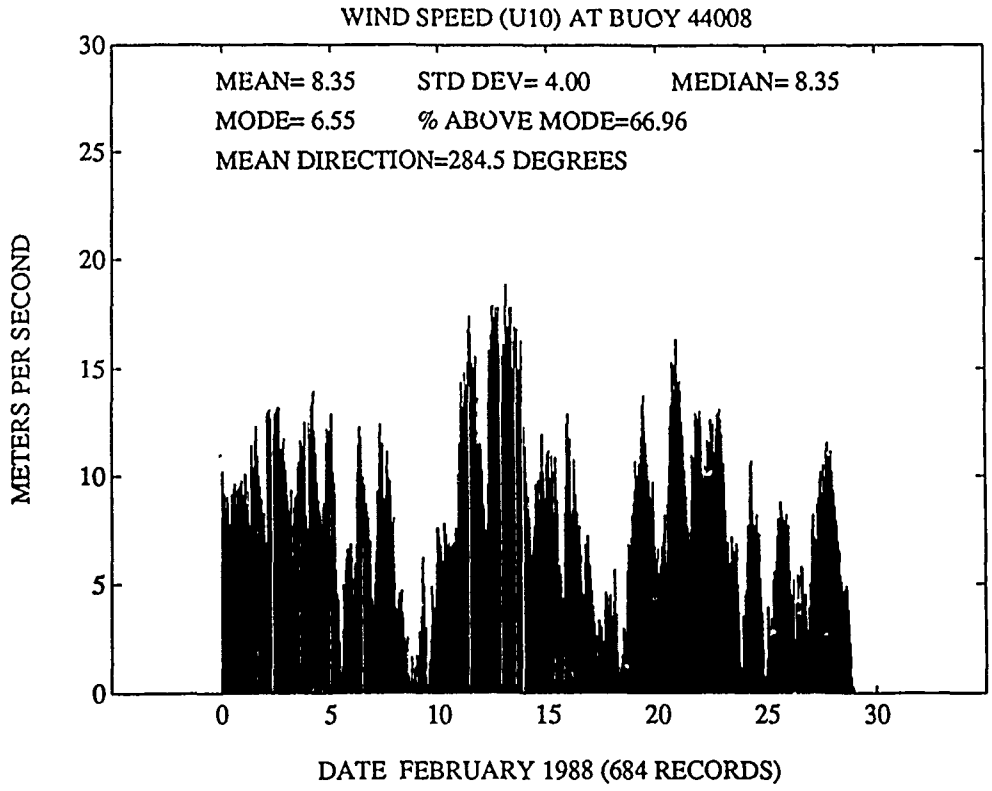


Figure 56: (continued) (c) Wind speed distribution, and (d) wind direction distribution.



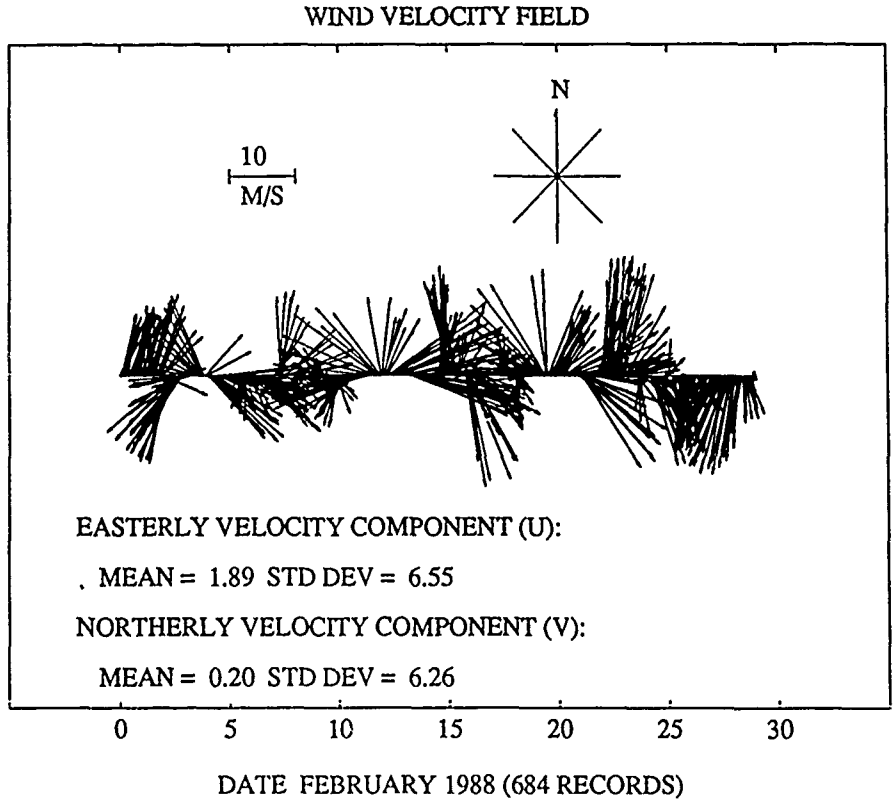
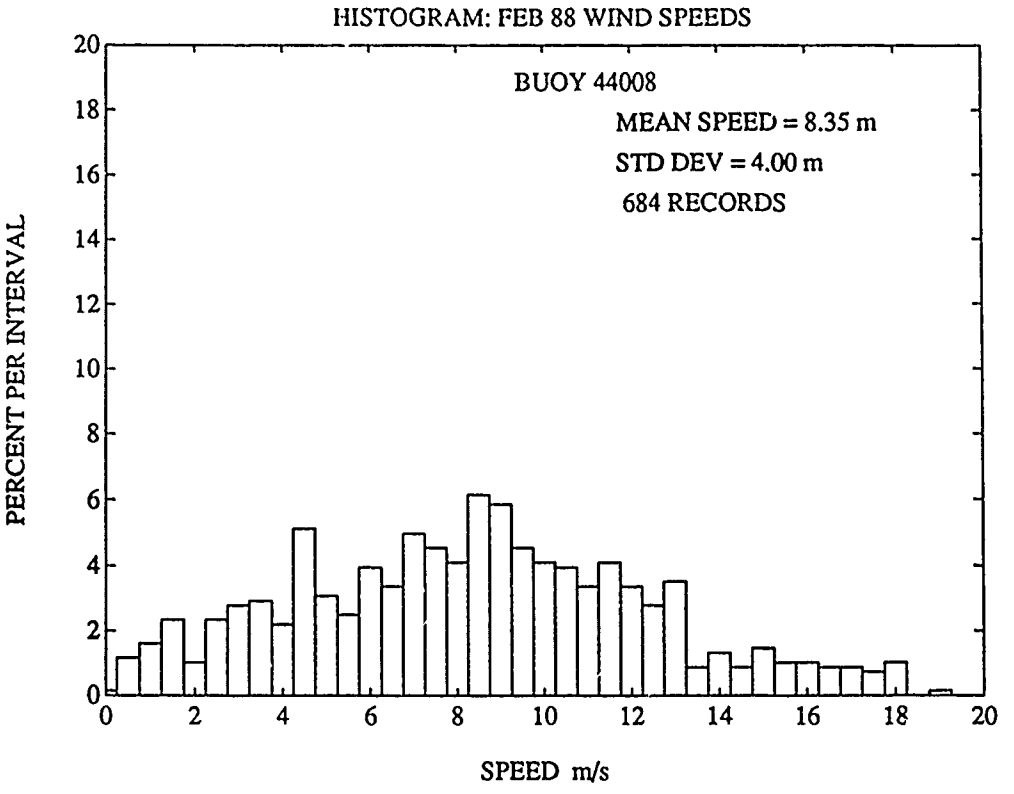


Figure 57: Wind speed and direction at Buoy 44008, February 1988. (a) Wind speed time series, and (b) wind velocity vector plot.



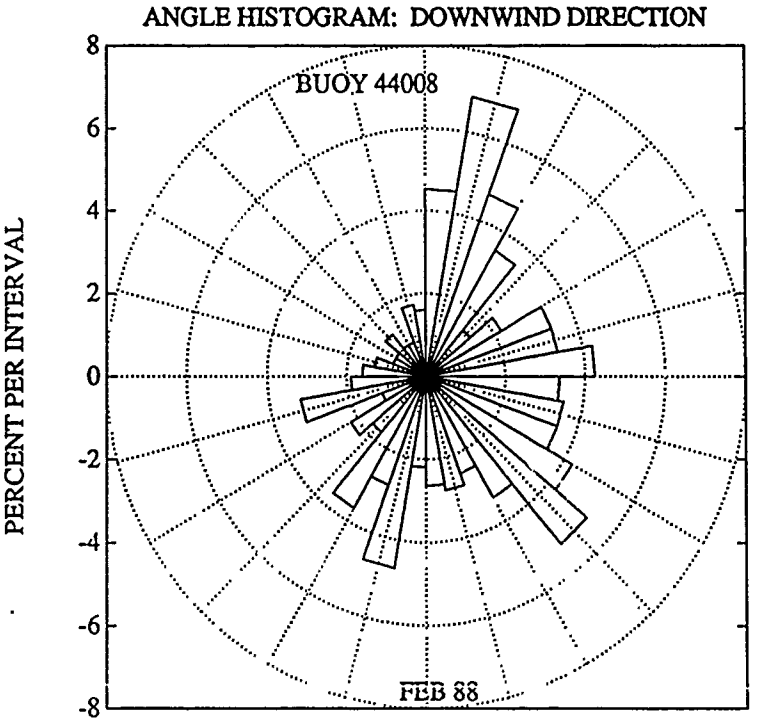
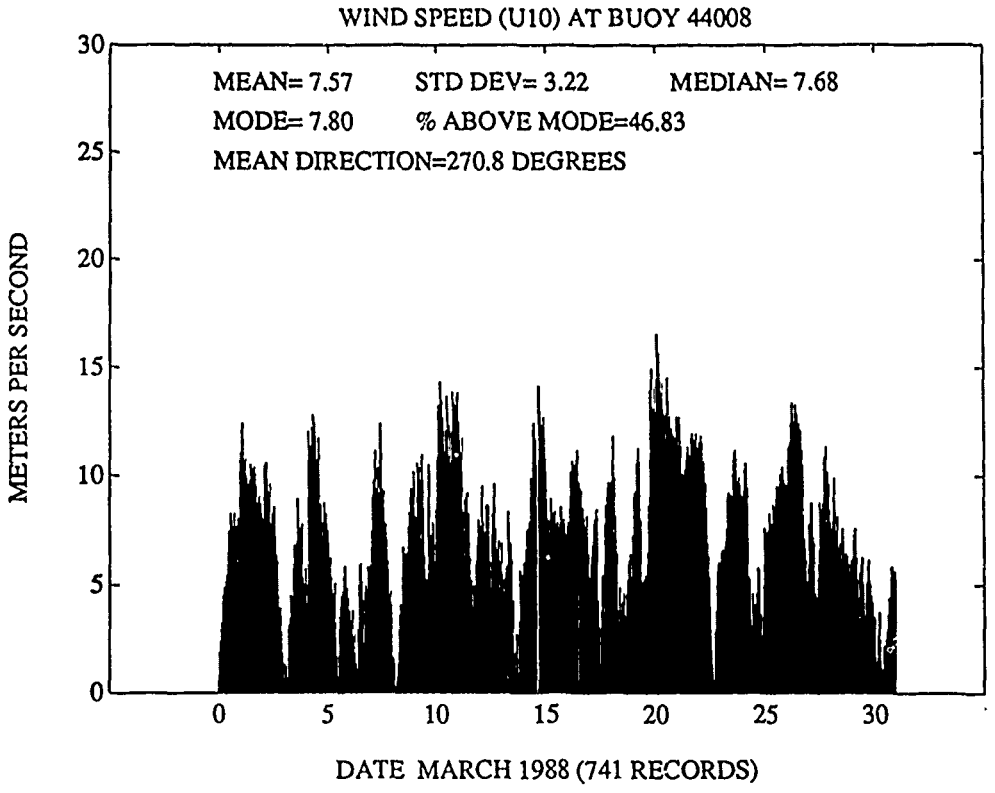


Figure 57: (continued) (c) Wind speed distribution, and (d) wind direction distribution.



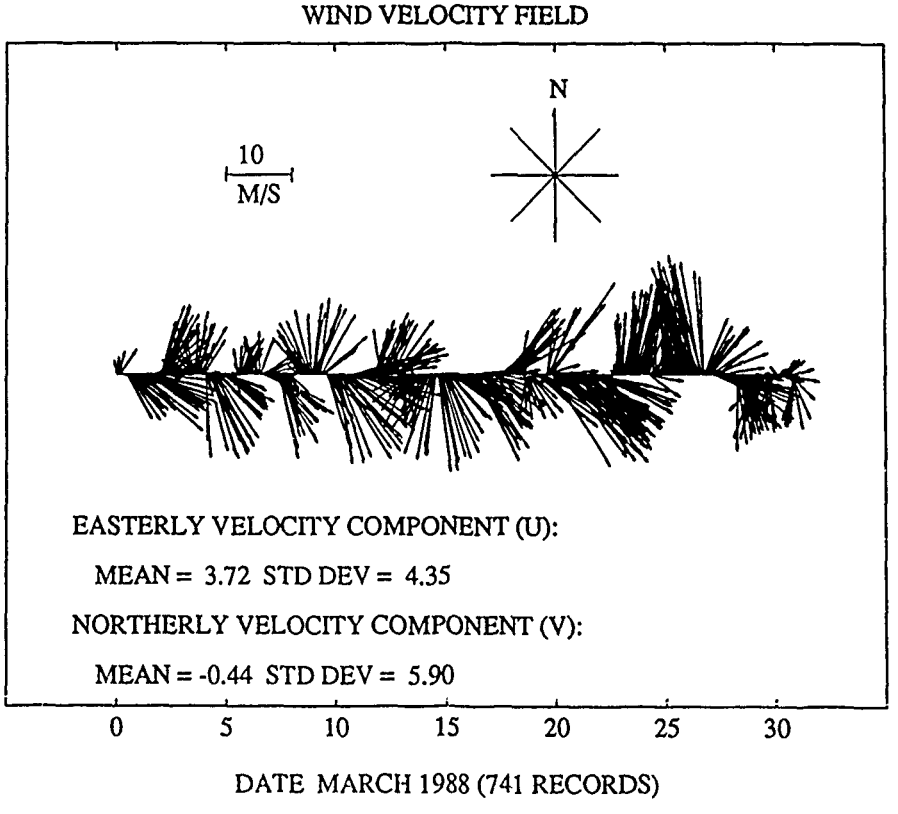
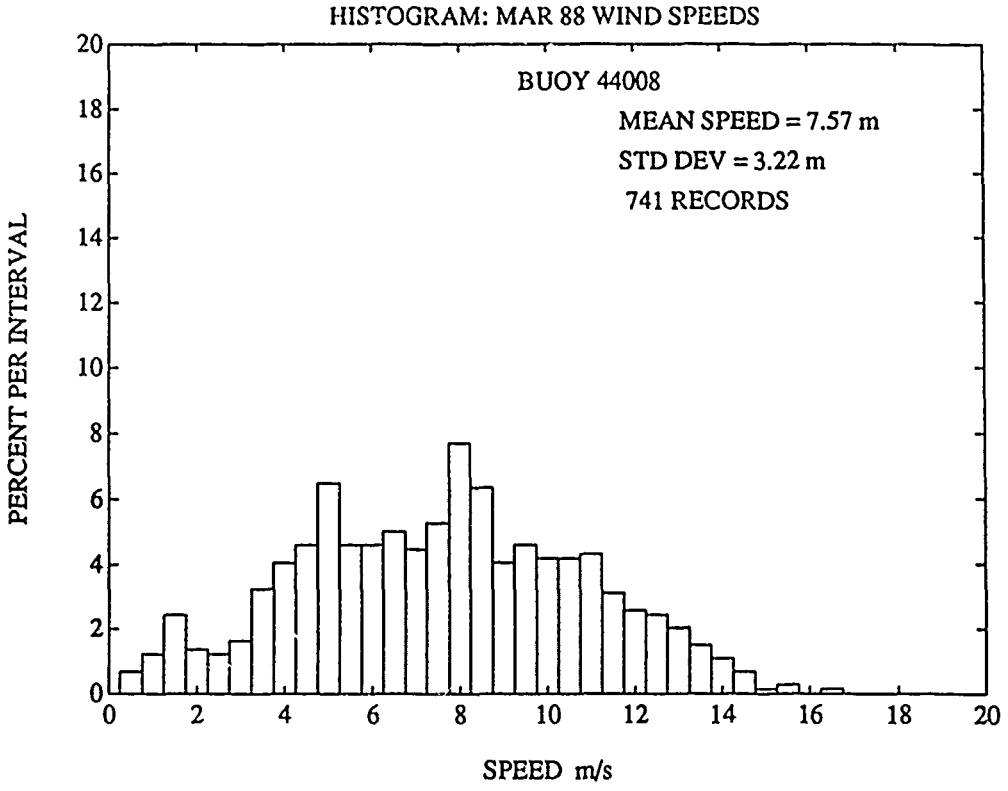


Figure 58: Wind speed and direction at Buoy 44008, March 1988. (a) Wind speed time series, and (b) wind velocity vector plot.



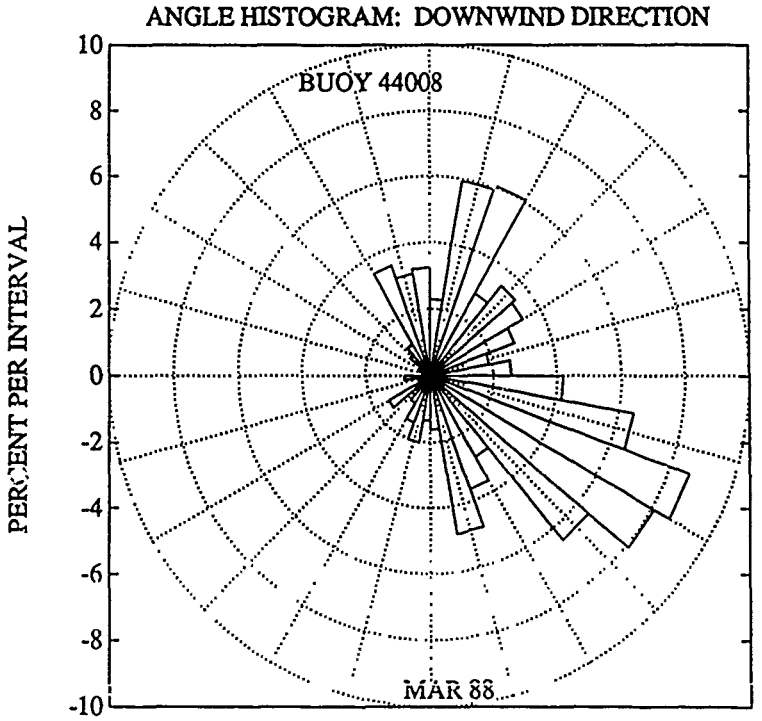
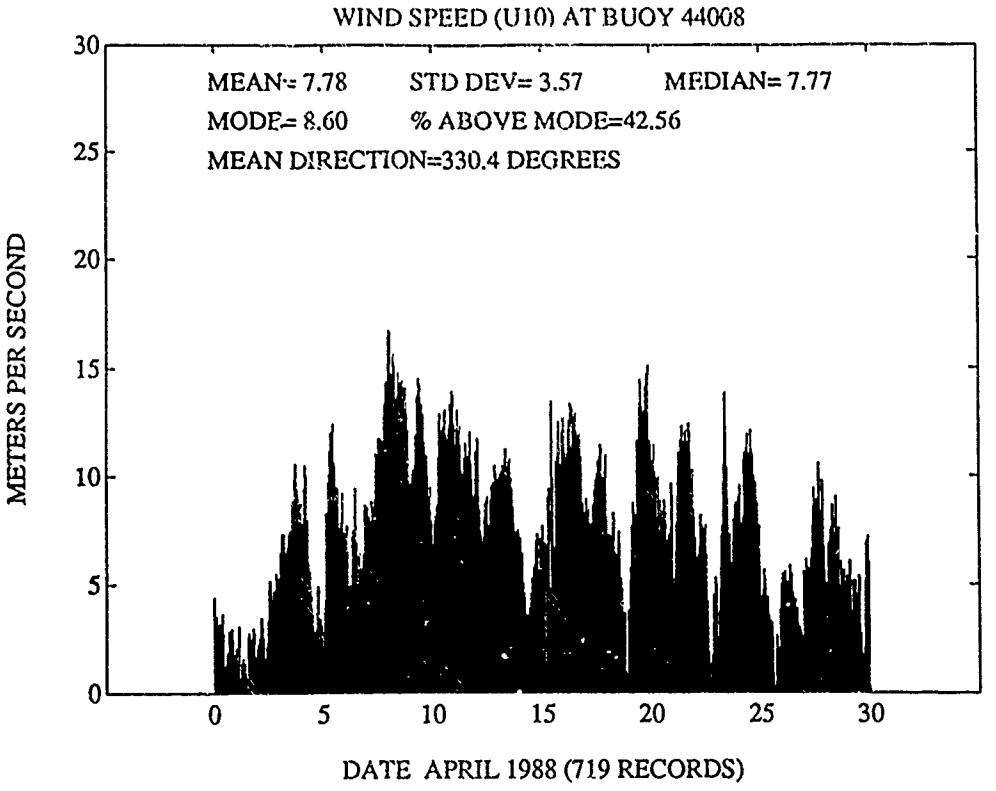


Figure 58: (continued) (c) Wind speed distribution, and (d) wind direction distribution.



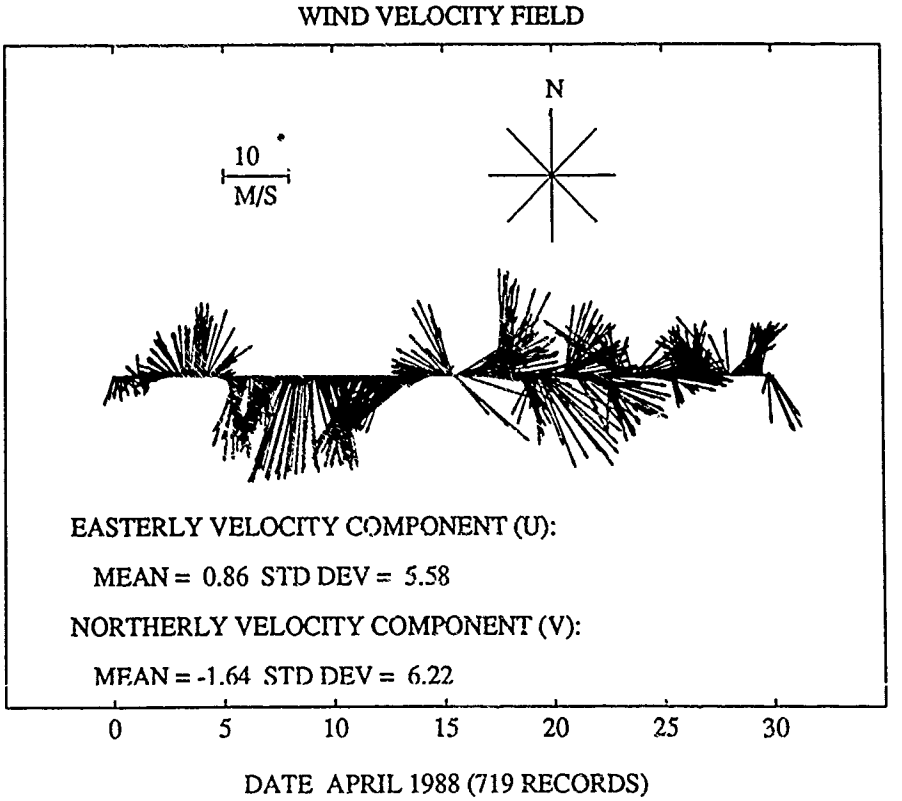
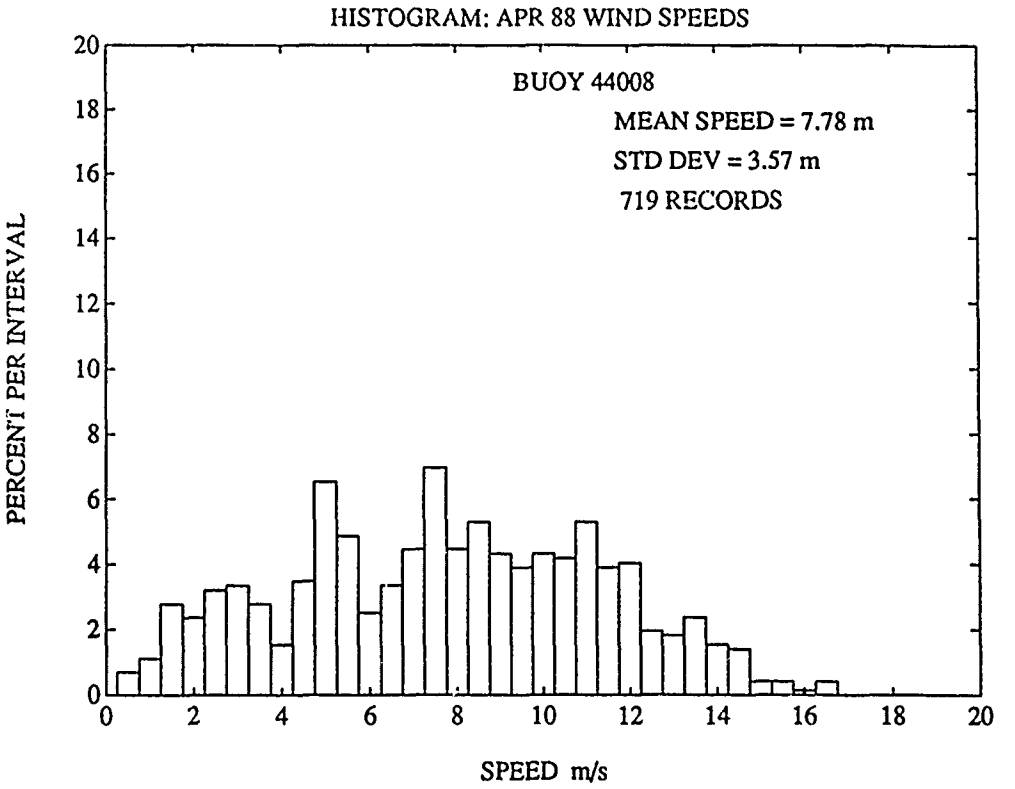


Figure 59: Wind speed and direction at Buoy 44008, April 1988. (a) Wind speed time series, and (b) wind velocity vector plot.



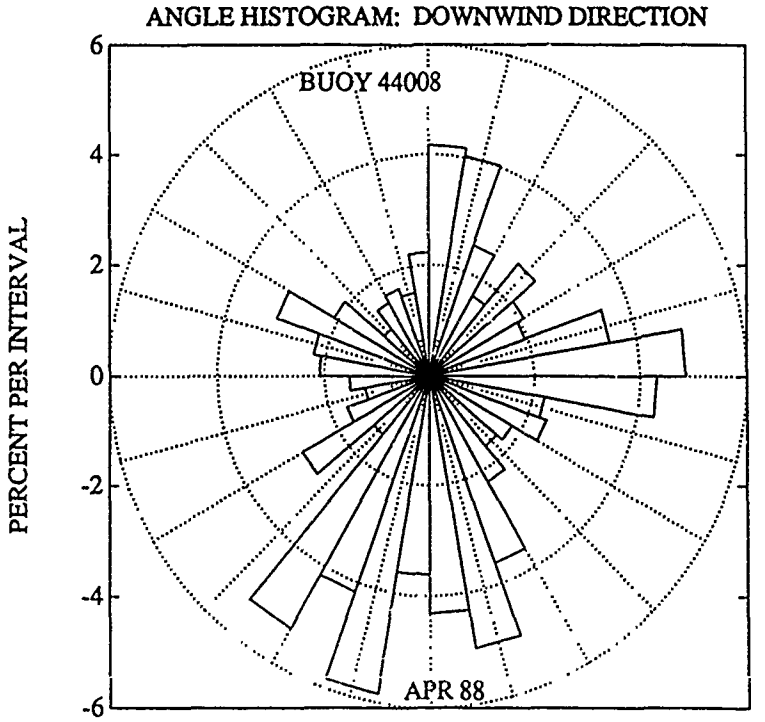
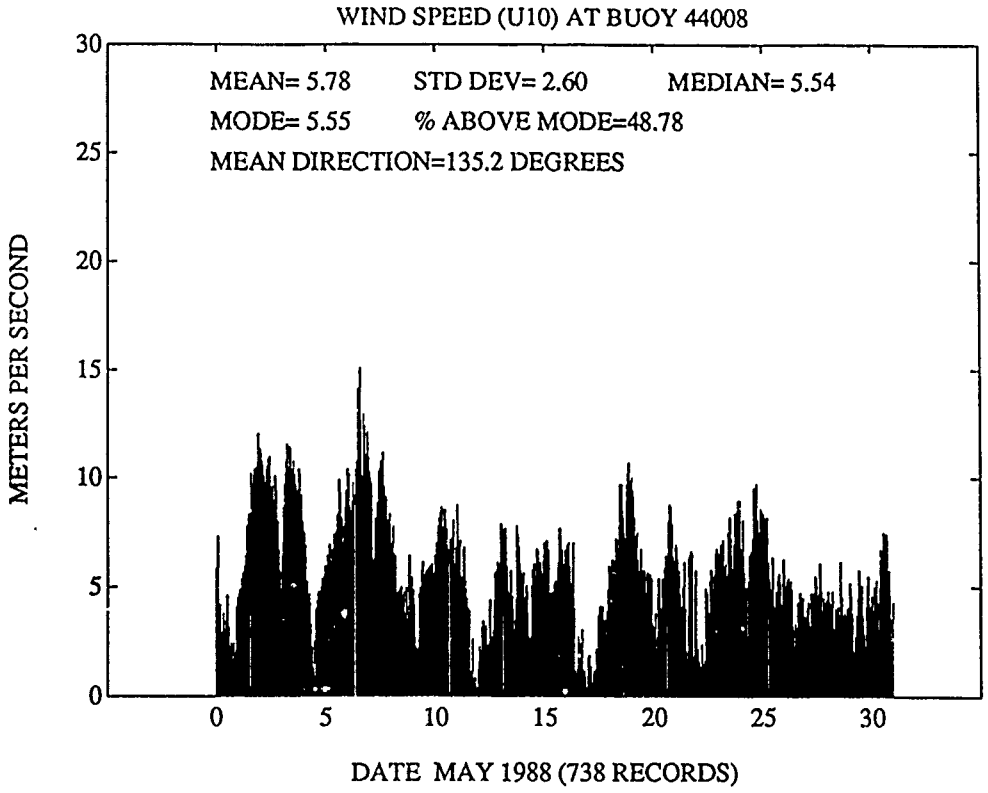


Figure 59: (continued) (c) Wind speed distribution, and (d) wind direction distribution.



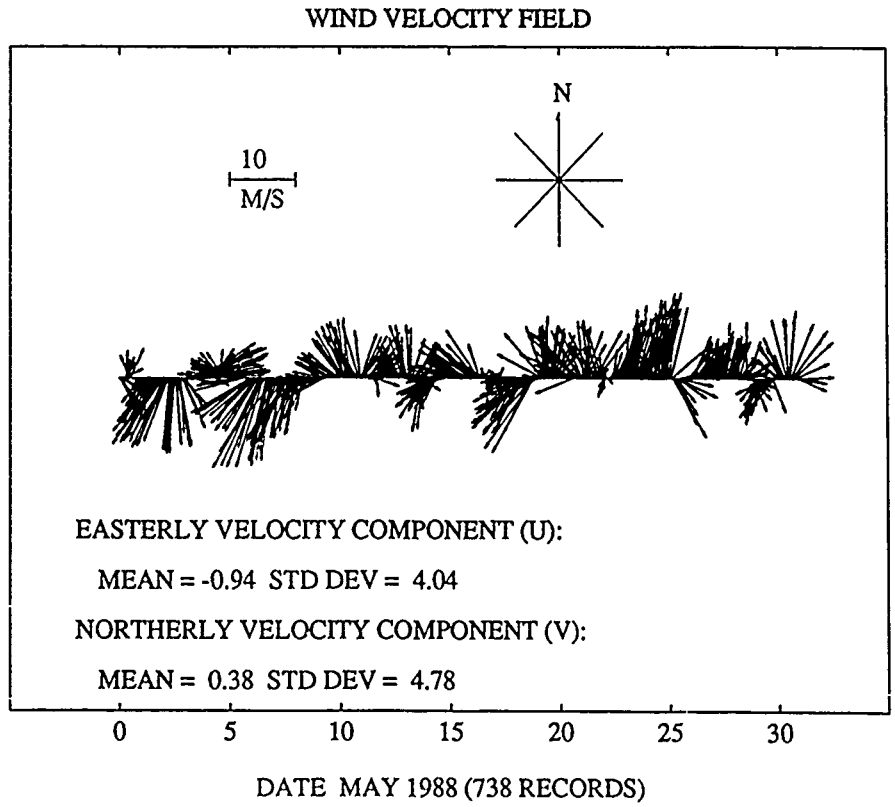
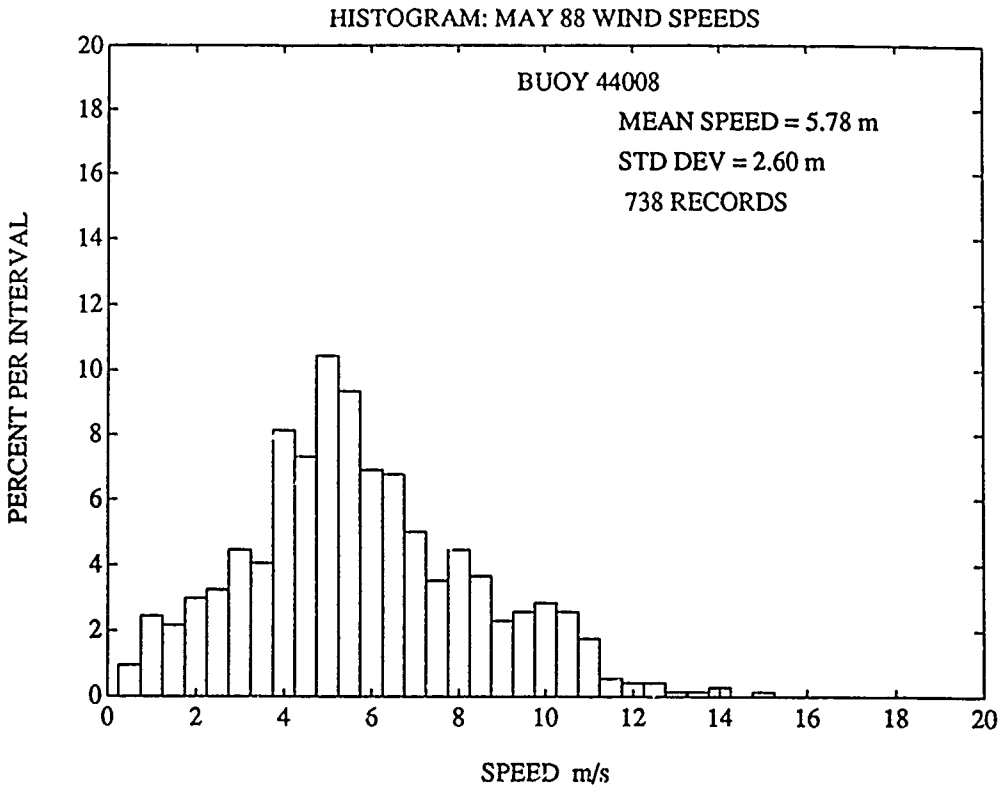


Figure 60: Wind speed and direction at Buoy 44008, May 1988. (a) Wind speed time series, and (b) wind velocity vector plot.



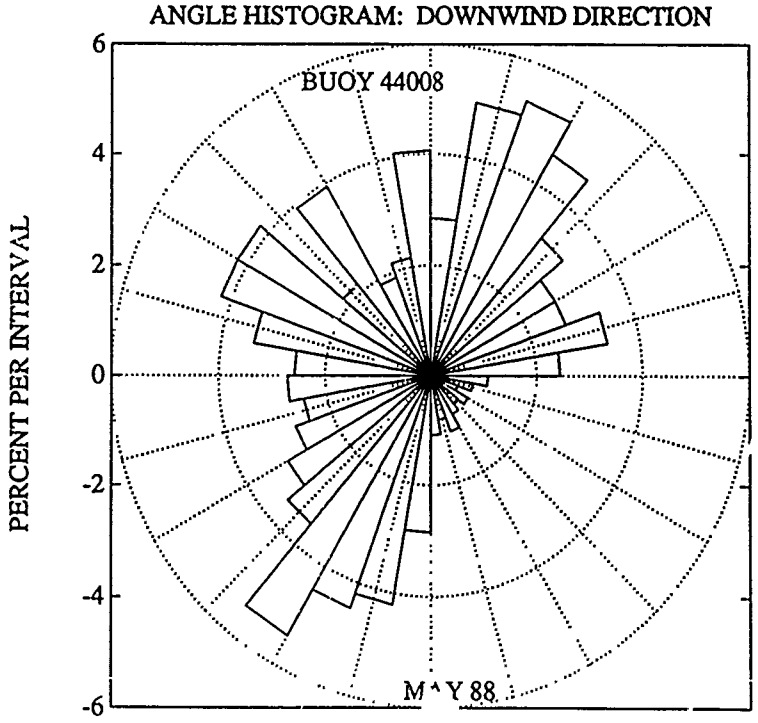
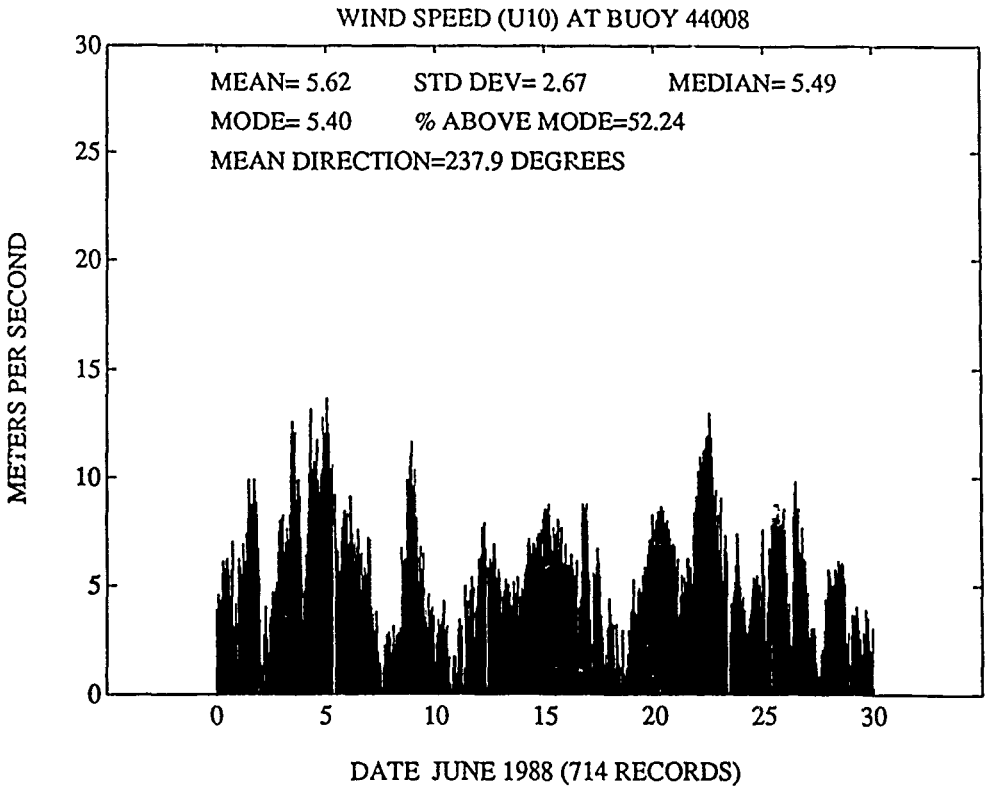


Figure 60: (continued) (c) Wind speed distribution, and (d) wind direction distribution.



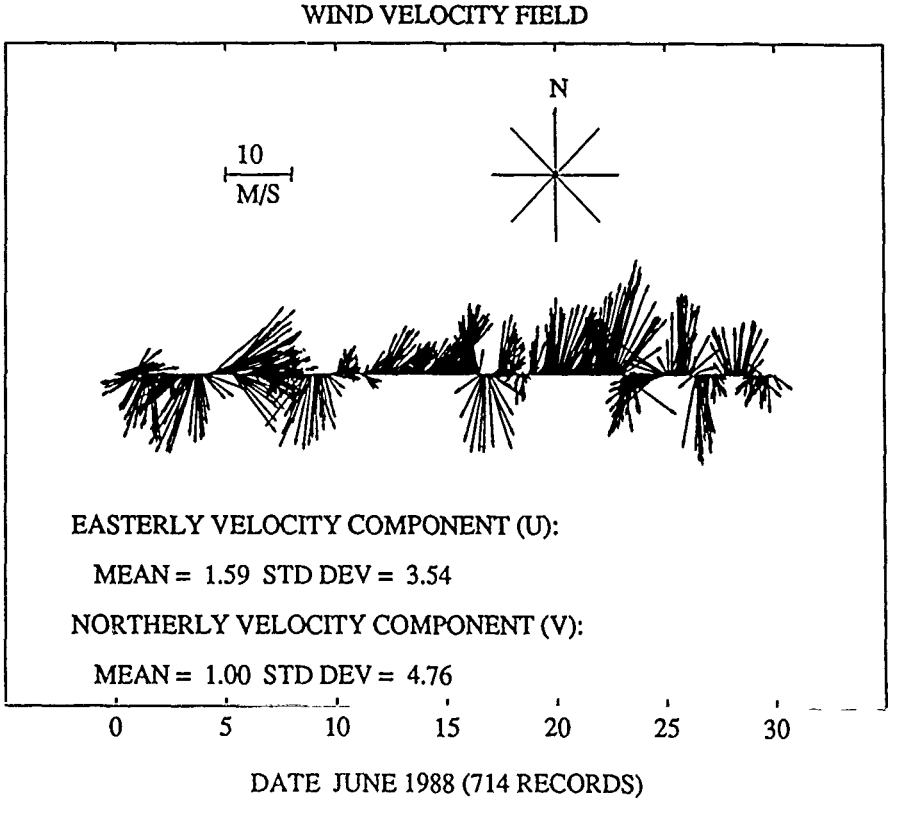


Figure 61: Wind speed and direction at Buoy 44008, June 1988. (a) Wind speed time series, and (b) wind velocity vector plot.

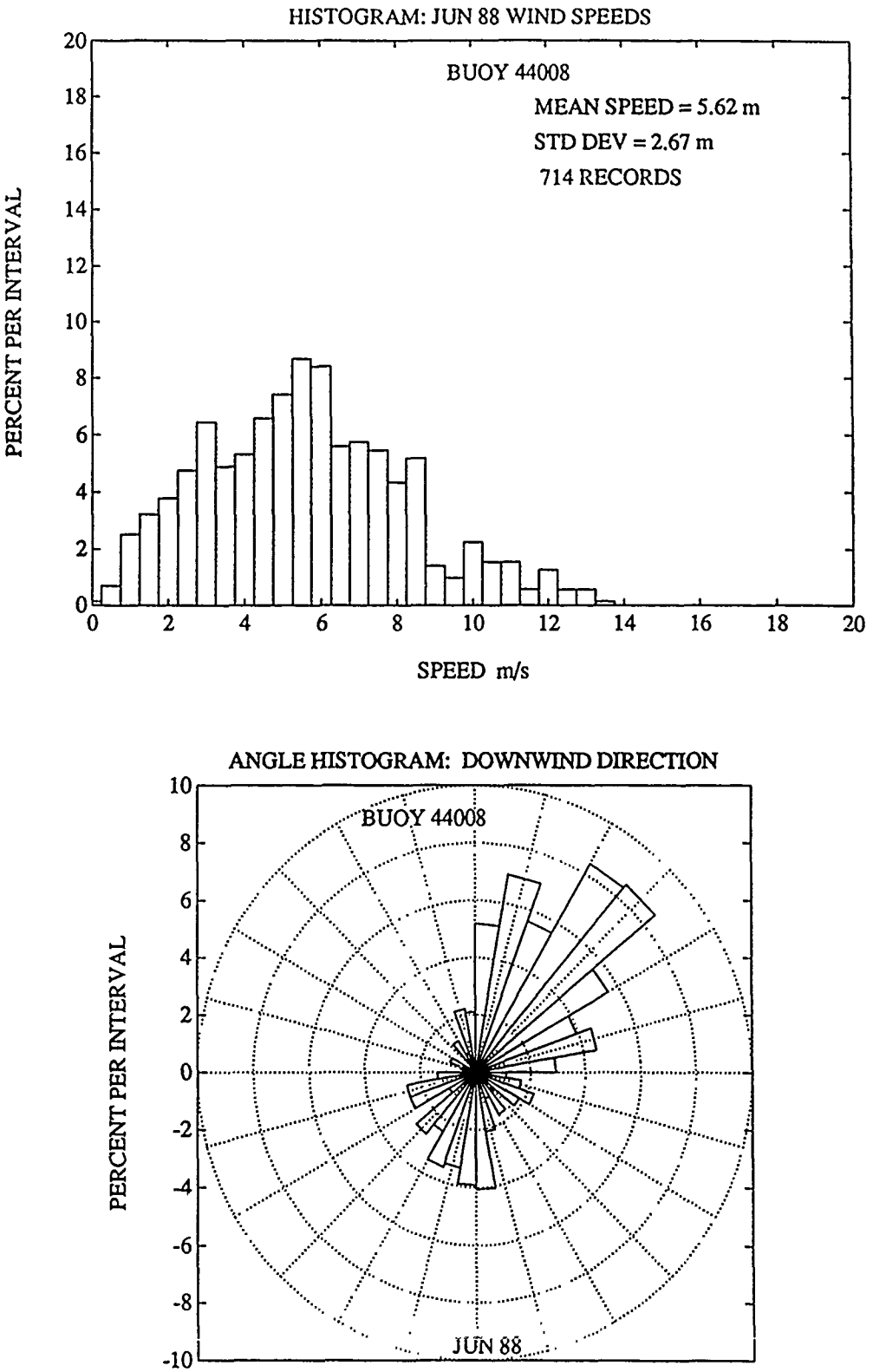
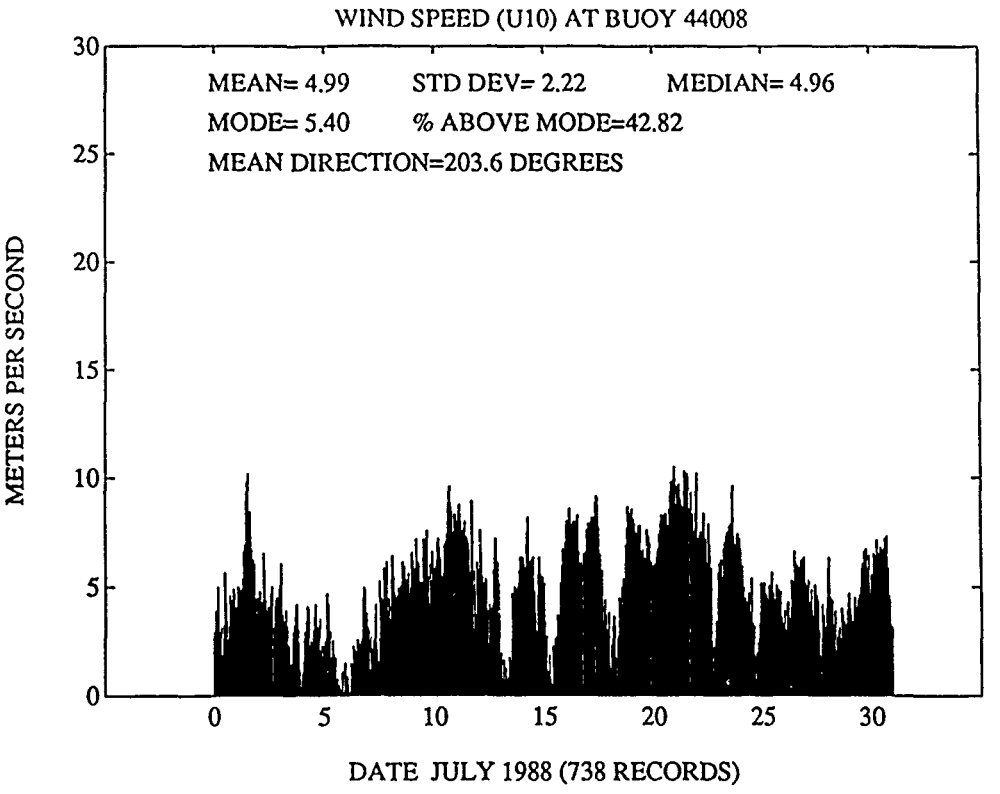


Figure 61: (continued) (c) Wind speed distribution, and (d) wind direction distribution.



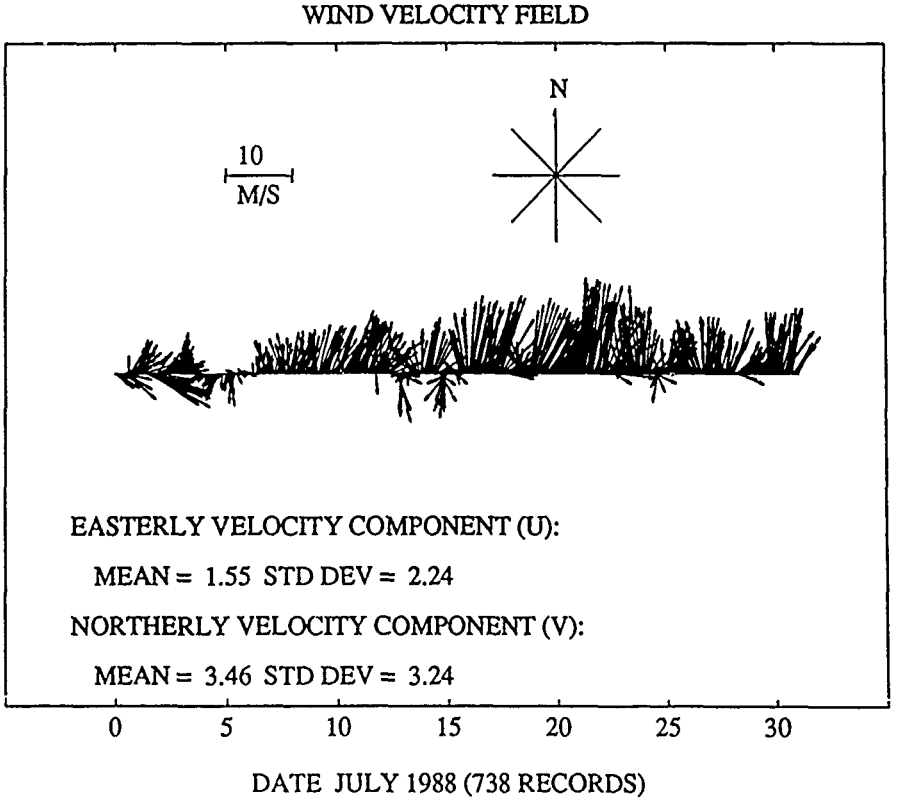
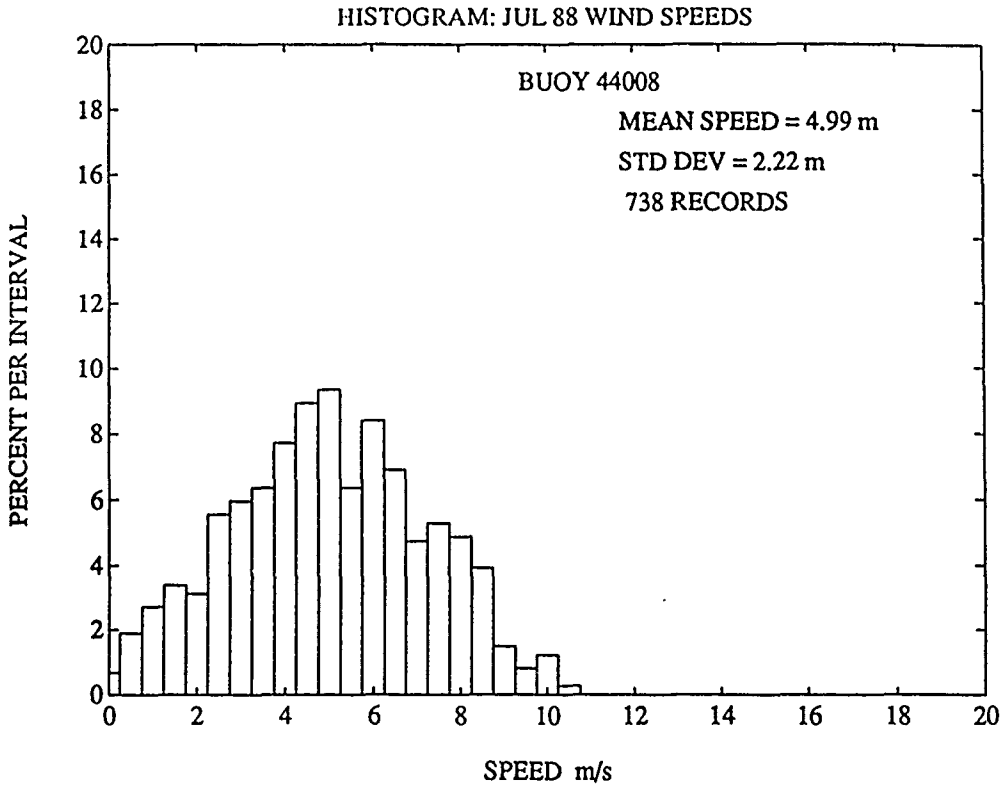


Figure 62: Wind speed and direction at Buoy 44008, July 1988. (a) Wind speed time series, and (b) wind velocity vector plot.



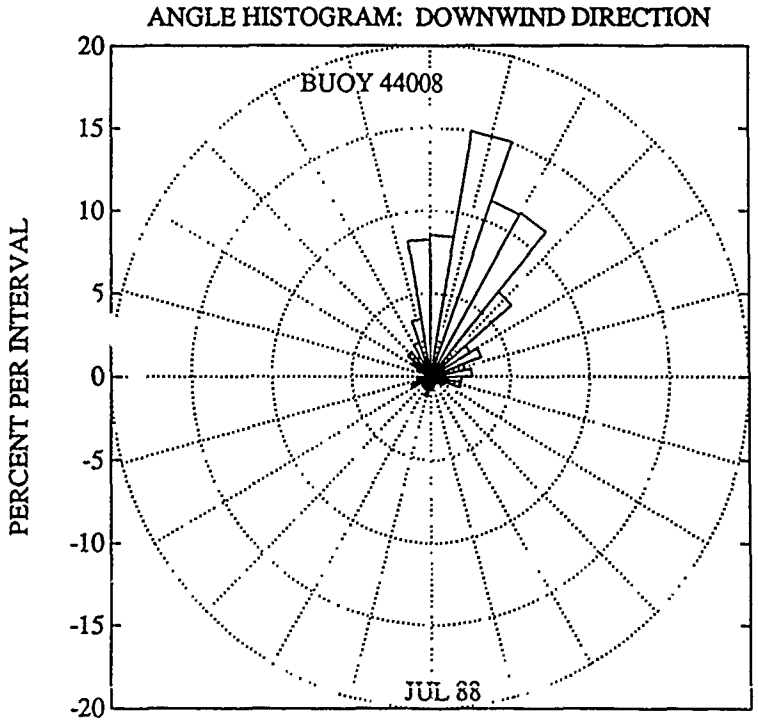
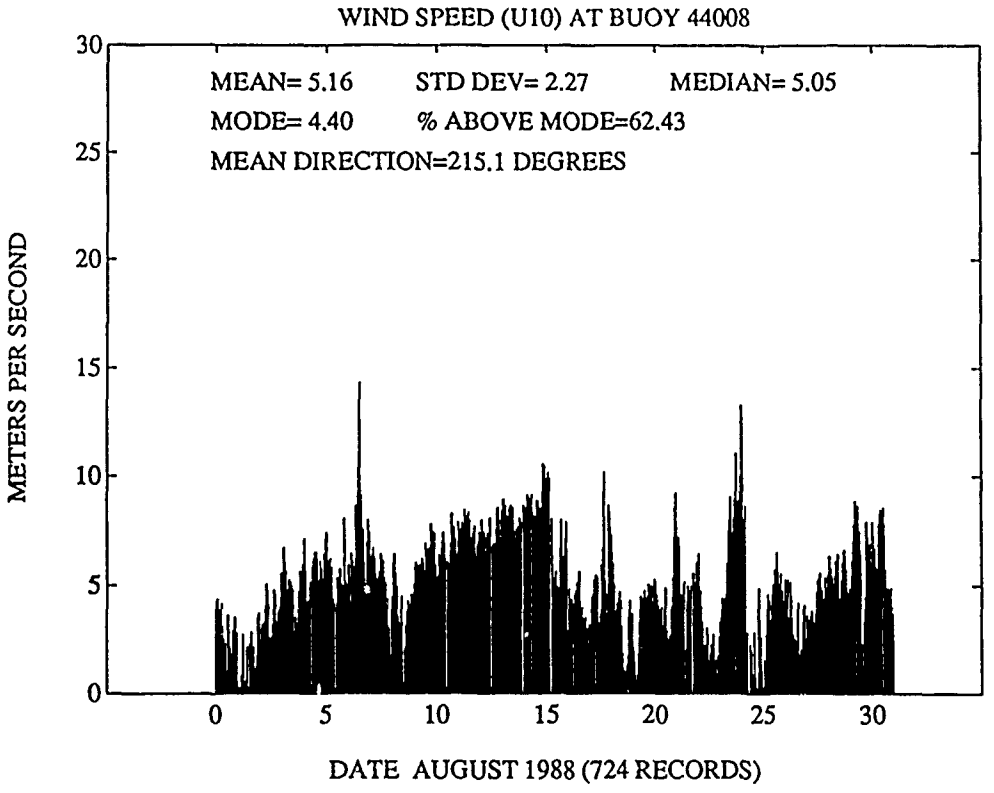


Figure 62: (continued) (c) Wind speed distribution, and (d) wind direction distribution.



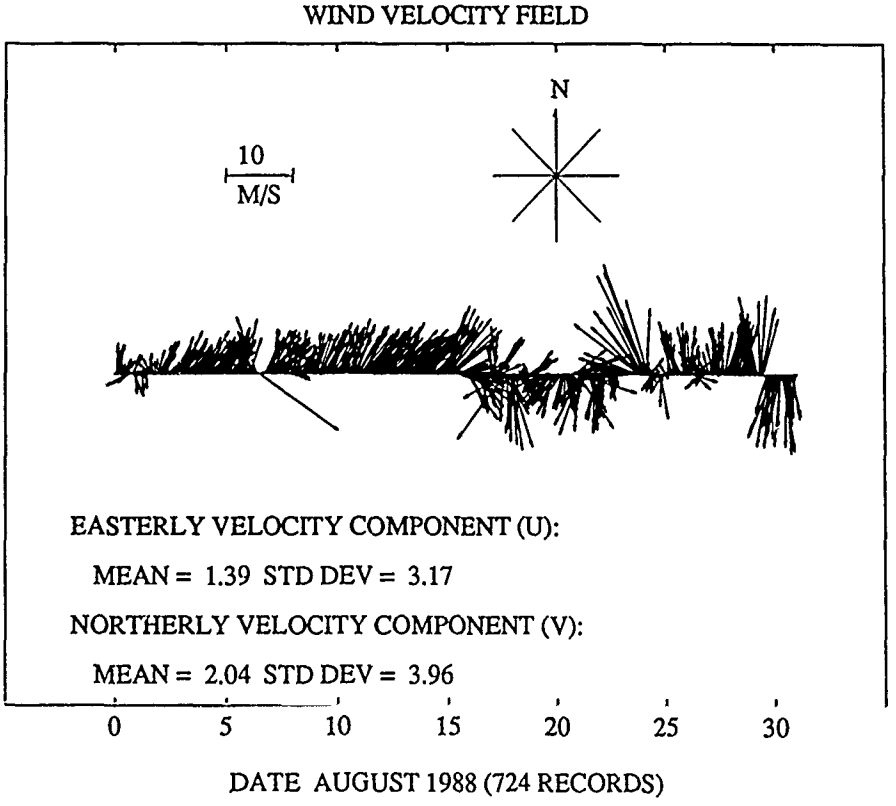
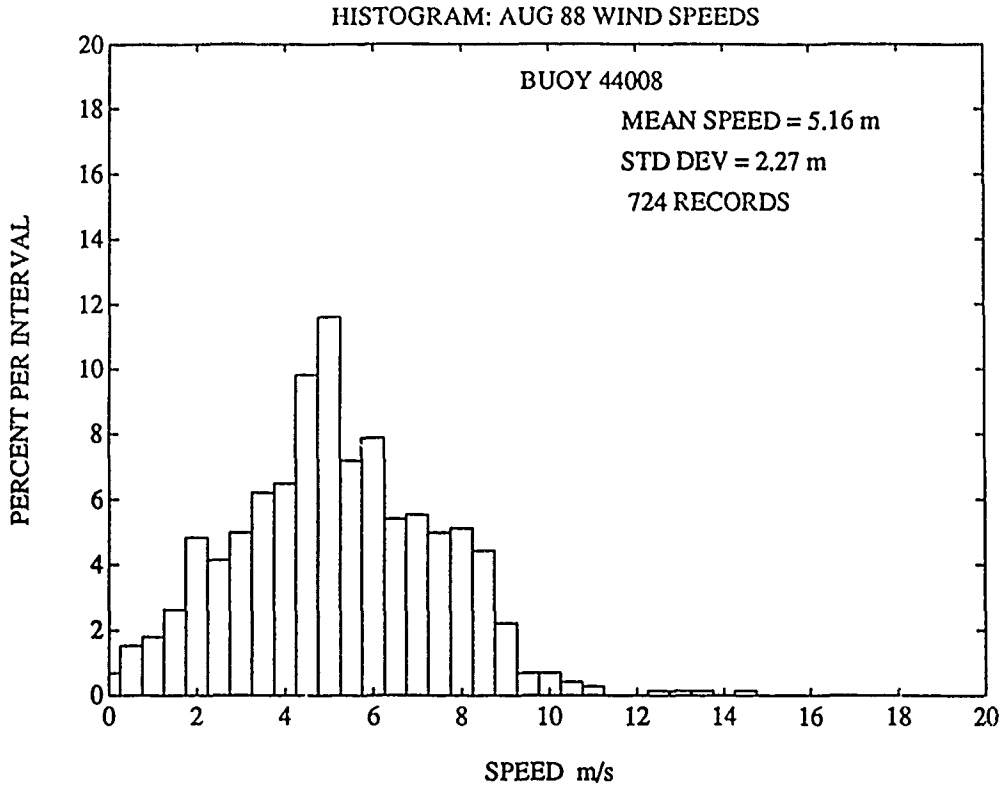


Figure 63: Wind speed and direction at Buoy 44008, August 1988. (a) Wind speed time series, and (b) wind velocity vector plot.



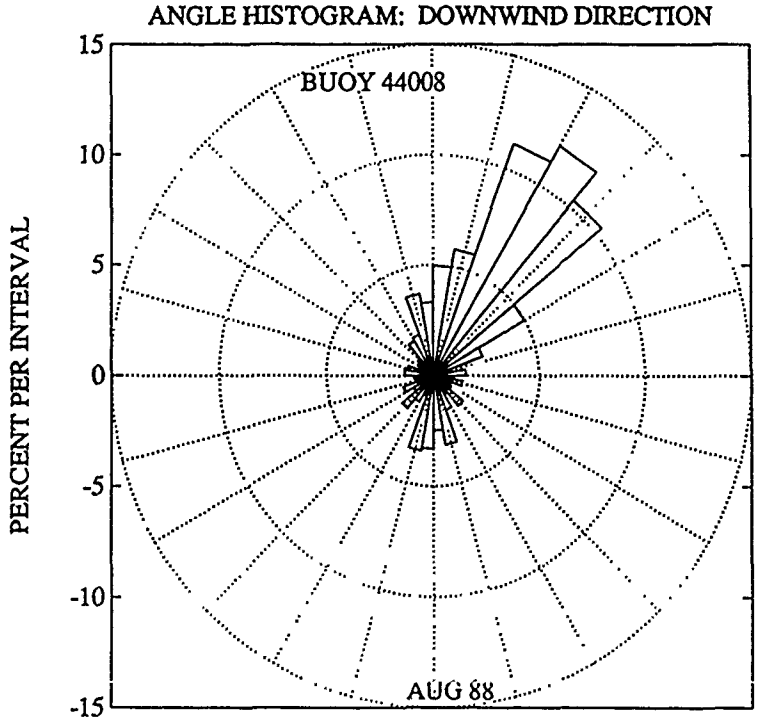


Figure 63: (continued) (c) Wind speed distribution, and (d) wind direction distribution.

B Wave Height and Period Monthly and Seasonal Summaries

Heights are in meters.
Periods are in seconds.

DATE	H_s			T_m			$\bar{T}$			REC-
YYMM	MIN	MEAN	MAX	MIN	MEAN	MAX	MIN	MEAN	MAX	ORDS
MAY 87	0.52	0.88	1.64	2.90	7.68	10.70	3.76	5.53	7.58	231
JUN 87	0.39	1.09	2.66	2.30	6.90	10.70	3.58	4.87	6.54	435
JUL 87	0.29	0.69	1.92	2.50	6.80	16.00	3.44	5.06	6.59	533
AUG 87	0.31	0.81	2.60	2.50	6.88	12.80	3.34	4.97	8.32	525
SEP 87	0.33	0.80	2.46	2.50	6.72	10.70	3.41	5.07	7.98	388
OCT 87	0.43	1.15	3.28	2.80	6.96	11.60	3.56	5.21	9.00	660
NOV 87	0.24	1.31	3.32	2.20	6.47	16.00	3.19	4.88	8.39	598
DEC 87	0.39	1.37	3.50	2.40	6.79	14.20	3.25	4.94	8.52	363
JAN 88	0.74	1.59	2.34	2.10	6.22	9.10	3.54	4.90	5.64	49
FEB 88	0.35	1.31	3.75	2.80	8.39	12.80	3.75	5.68	9.25	400
MAR 88	0.28	1.06	2.25	2.30	6.73	14.20	3.24	4.87	7.61	373
APR 88	0.41	1.13	2.31	2.70	6.61	12.80	3.46	5.13	8.64	659
MAY 88	0.40	0.95	2.54	2.80	6.94	11.60	3.62	5.19	7.59	566
JUN 88	0.38	0.98	2.99	2.70	6.76	14.20	3.38	5.16	8.65	612
JUL 88	0.43	1.08	2.53	3.40	7.05	9.80	3.98	5.26	7.33	627
AUG 88	0.35	1.03	2.63	2.20	6.70	14.20	3.27	5.07	7.26	504

Table 2: Martha's Vineyard Buoy, Wave Height and Period Monthly Summaries

DATE	H_s			T_m			$\bar{T}$			REC-
YYMM	MIN	MEAN	MAX	MIN	MEAN	MAX	MIN	MEAN	MAX	ORDS
SPRING 87	0.52	0.88	1.64	2.90	7.68	10.70	3.76	5.53	7.58	231
SUMMER 87	0.29	0.85	2.66	2.30	6.86	16.00	3.34	4.97	8.32	1493
AUTUMN 87	0.24	1.12	3.32	2.20	6.72	16.00	3.19	5.06	9.00	1646
WINTER 88	0.35	1.35	3.75	2.10	7.55	14.20	3.25	5.30	9.25	812
SPRING 88	0.28	1.05	2.54	2.30	6.76	14.20	3.24	5.09	8.64	1598
SUMMER 88	0.35	1.03	2.99	2.20	6.85	14.20	3.27	5.17	8.65	1743

Table 3: Martha's Vineyard Buoy, Wave Height and Period Seasonal Summaries

DATE	H_s			T_m			$\bar{T}$			REC-
YYMM	MIN	MEAN	MAX	MIN	MEAN	MAX	MIN	MEAN	MAX	ORDS
MAY 87	0.60	1.54	4.08	3.80	7.58	14.30	3.94	5.66	7.55	742
JUN 87	0.50	1.34	2.79	3.30	6.97	11.10	3.93	5.32	6.96	717
JUL 87	0.44	1.20	2.07	3.60	6.00	12.50	3.91	5.05	6.77	270
AUG 87	0.47	1.24	3.00	2.90	7.57	12.50	3.80	5.68	9.37	741
SEP 87	0.48	1.31	2.63	3.40	7.65	12.50	3.86	5.66	7.79	682
OCT 87	0.67	1.95	5.81	3.60	8.10	11.10	3.98	6.10	8.31	738
NOV 87	0.55	2.14	7.31	3.60	7.93	14.30	3.85	5.86	9.32	300
DEC 87	0.69	2.67	7.95	3.00	8.22	14.30	3.63	6.22	9.92	272
JAN 88	0.79	2.42	5.97	3.80	8.59	14.30	4.14	6.57	12.14	185
FEB 88	1.20	2.38	5.05	4.20	7.90	12.50	4.18	6.12	9.17	242
MAR 88	0.78	2.16	6.38	3.40	7.85	12.50	3.74	5.90	9.69	743
APR 88	0.60	2.26	4.82	3.10	8.37	14.30	3.77	6.23	8.80	718
MAY 88	0.65	1.60	4.54	3.40	8.17	12.50	3.92	5.94	9.56	741
JUN 88	0.58	1.53	4.71	3.40	6.93	12.50	3.68	5.44	8.23	720
JUL 88	0.51	1.30	2.79	3.70	7.30	12.50	3.85	5.59	7.64	742
AUG 88	0.65	1.39	3.80	2.90	6.67	10.00	3.72	5.23	7.21	741

Table 4: Buoy 44004, Wave Height and Period Monthly Summaries

DATE	H_s			T_m			$\bar{T}$			REC-
YYMM	MIN	MEAN	MAX	MIN	MEAN	MAX	MIN	MEAN	MAX	ORDS
SPRING 87	0.60	1.54	4.08	3.80	7.58	14.30	3.94	5.66	7.55	742
SUMMER 87	0.44	1.27	3.00	2.90	7.08	12.50	3.80	5.44	9.37	1728
AUTUMN 87	0.48	1.73	7.31	3.40	7.89	14.30	3.85	5.88	9.32	1720
WINTER 88	0.69	2.50	7.95	3.00	8.21	14.30	3.63	6.28	12.14	699
SPRING 88	0.60	2.01	6.38	3.10	8.13	14.30	3.74	6.02	9.69	2202
SUMMER 88	0.51	1.41	4.71	2.90	6.97	12.50	3.68	5.42	8.23	2203

Table 5: Buoy 44004, Wave Height and Period Seasonal Summaries

DATE	H_s			T_m			$\bar{T}$			REC-
YYMM	MIN	MEAN	MAX	MIN	MEAN	MAX	MIN	MEAN	MAX	ORDS
MAY 87	0.62	1.22	3.61	3.30	7.93	12.50	3.81	5.93	8.05	654
JUN 87	0.32	1.14	2.58	3.30	7.54	11.10	4.02	5.94	7.97	716
JUL 87	0.31	0.77	1.78	3.30	7.08	11.10	3.81	5.79	8.16	738
AUG 87	0.41	0.99	2.20	3.60	8.14	12.50	4.24	6.33	9.86	742
SEP 87	0.42	1.19	3.13	3.20	8.14	14.30	4.29	6.40	9.67	678
OCT 87	0.64	1.56	4.69	4.00	8.08	11.10	4.43	6.51	8.69	601
NOV 87					No Data					
DEC 87					No Data					
JAN 88					No Data					
FEB 88	0.65	1.95	3.78	3.80	8.59	12.50	4.21	6.75	9.70	251
MAR 88	0.56	1.75	4.23	3.40	7.93	12.50	4.38	6.42	9.84	740
APR 88	0.59	1.96	4.82	4.50	8.60	14.30	4.70	6.91	9.57	719
MAY 88	0.47	1.27	3.49	4.30	8.22	12.50	4.57	6.53	8.34	738
JUN 88	0.42	1.21	3.46	2.90	7.42	16.70	3.67	6.21	9.04	703
JUL 88	0.48	1.13	2.59	3.40	7.57	12.50	4.17	6.25	7.77	724
AUG 88	0.45	1.16	4.25	2.90	7.44	14.30	3.98	6.13	8.32	697

Table 6: Buoy 44008, Wave Height and Period Monthly Summaries

DATE	H_s			T_m			$\bar{T}$			REC-
YYMM	MIN	MEAN	MAX	MIN	MEAN	MAX	MIN	MEAN	MAX	ORDS
SPRING 87	0.62	1.22	3.61	3.30	7.93	12.50	3.81	5.93	8.05	654
SUMMER 87	0.31	0.97	2.58	3.30	7.59	12.50	3.81	6.02	9.86	2196
AUTUMN 87	0.42	1.36	4.69	3.20	8.11	14.30	4.29	6.45	9.67	1279
WINTER 88	0.65	1.95	3.78	3.80	8.59	12.50	4.21	6.75	9.70	251
SPRING 88	0.47	1.66	4.82	3.40	8.25	14.30	4.38	6.62	9.84	2197
SUMMER 88	0.42	1.17	4.25	2.90	7.48	16.70	3.67	6.20	9.04	2124

Table 7: Buoy 44008, Wave Height and Period Seasonal Summaries

DATE	H_s			T_m			$\bar{T}$			REC-
YYMM	MIN	MEAN	MAX	MIN	MEAN	MAX	MIN	MEAN	MAX	ORDS
MAY 87	0.69	1.45	3.95	4.20	7.86	12.50	4.03	5.84	8.79	743
JUN 87	0.57	1.41	3.07	3.70	7.49	10.00	3.87	5.70	7.55	719
JUL 87	0.50	0.99	1.68	3.20	6.63	11.10	3.64	5.32	6.62	449
AUG 87	0.50	1.13	2.72	2.90	7.88	12.50	3.52	5.92	9.96	743
SEP 87	0.55	1.36	3.31	3.20	7.76	14.30	3.96	5.96	10.73	680
OCT 87	0.80	1.89	6.24	4.30	8.52	11.10	4.55	6.33	8.93	743
NOV 87	0.56	2.33	6.11	3.30	8.27	14.30	3.94	6.26	8.83	717
DEC 87	0.74	3.01	8.16	3.70	8.74	12.50	3.91	6.64	9.75	439
JAN 88	0.58	2.38	6.72	3.60	8.59	12.50	3.89	6.59	9.75	742
FEB 88	0.70	2.65	7.77	3.20	8.52	12.50	3.70	6.50	10.48	579
MAR 88	0.91	2.48	4.69	4.30	8.60	12.50	4.46	6.47	8.65	112
APR 88					No Data					
MAY 88	0.73	1.21	2.67	4.00	8.19	11.10	4.58	5.96	8.48	263
JUN 88	0.57	1.61	5.75	3.20	7.40	11.10	3.66	5.85	9.09	719
JUL 88	0.64	1.33	2.31	3.20	7.37	14.30	3.76	5.78	7.60	739
AUG 88	0.54	1.34	4.30	2.60	7.35	11.10	3.57	5.49	7.89	729

Table 8: Buoy 44011, Wave Height and Period Monthly Summaries

DATE	H_s			T_m			$\bar{T}$			REC-
YYMM	MIN	MEAN	MAX	MIN	MEAN	MAX	MIN	MEAN	MAX	ORDS
SPRING 87	0.69	1.45	3.95	4.20	7.86	12.50	4.03	5.84	8.79	743
SUMMER 87	0.50	1.20	3.07	2.90	7.44	12.50	3.52	5.69	9.96	1911
AUTUMN 87	0.55	1.87	6.24	3.20	8.20	14.30	3.94	6.19	10.73	2140
WINTER 88	0.58	2.63	8.16	3.20	8.60	12.50	3.70	6.58	10.48	1760
SPRING 88	0.73	1.59	4.69	4.00	8.32	12.50	4.46	6.11	8.65	375
SUMMER 88	0.54	1.42	5.75	2.60	7.37	14.30	3.57	5.71	9.09	2187

Table 9: Buoy 44011, Wave Height and Period Seasonal Summaries

C Wind Speed and Direction Monthly and Seasonal Summaries

Speeds in meters per second.
Directions in degrees from true north.

DATE	WIND SPEED			MEAN DIRECTION		RECORDS
YYMM	MIN	MEAN	MAX	(WEIGHTED)	(UNWEIGHTED)	
MAY 87	0.46	6.56	15.18	053.4	025.8	735
JUN 87	0.46	6.23	13.45	042.2	034.9	708
JUL 87	0.46	4.80	10.83	015.3	013.4	718
AUG 87	0.46	5.50	13.45	055.8	057.9	727
SEP 87	0.46	6.13	16.47	018.1	025.9	669
OCT 87	0.46	6.57	16.90	071.4	070.1	740
NOV 87	0.46	8.27	19.45	060.7	082.4	713
DEC 87	0.46	7.77	18.17	110.3	110.9	742
JAN 88	0.46	7.36	17.75	082.8	085.3	738
FEB 88	0.46	7.45	17.75	074.3	083.5	691
MAR 88	0.46	6.96	17.75	079.3	079.8	740
APR 88	0.46	7.38	14.31	132.0	102.9	718
MAY 88	0.46	5.92	13.88	330.5	352.2	735
JUN 88	0.46	6.02	13.02	056.4	055.6	709
JUL 88	0.19	5.68	12.37	031.3	031.5	726
AUG 88	0.13	6.17	14.36	035.3	035.1	727

Table 10: Buzzards Bay Tower, Wind Speed and Direction Monthly Summaries

DATE	WIND SPEED			MEAN DIRECTION		RECORDS
YYMM	MIN	MEAN	MAX	(WEIGHTED)	(UNWEIGHTED)	
SPRING 87	0.46	6.56	15.18	053.4	025.8	735
SUMMER 87	0.46	5.51	13.45	037.7	027.6	2153
AUTUMN 87	0.46	7.00	19.45	073.4	062.1	2122
WINTER 88	0.46	7.53	18.17	091.9	095.3	2171
SPRING 88	0.46	6.75	17.75	087.5	072.6	2193
SUMMER 88	0.13	5.96	14.36	039.9	039.3	2162

Table 11: Buzzards Bay Tower, Wind Speed and Direction Seasonal Summaries

DATE	WIND SPEED			MEAN DIRECTION		RECORDS
YYMM	MIN	MEAN	MAX	(WEIGHTED)	(UNWEIGHTED)	
MAY 87	0.00	6.55	12.80	053.0	044.3	560
JUN 87	0.00	5.92	12.63	062.3	065.7	719
JUL 87	0.00	5.43	10.25	017.1	021.1	272
AUG 87	0.00	4.58	10.27	237.1	257.5	433
SEP 87	0.00	4.99	11.47	022.6	013.5	639
OCT 87	0.07	6.66	15.61	176.6	190.9	669
NOV 87	2.99	2.99	2.99	182.6	182.6	1
DEC 87	0.77	9.50	21.33	131.3	134.2	178
JAN 88	0.07	8.19	16.96	135.7	147.7	203
FEB 88	1.10	7.70	15.23	139.4	130.4	242
MAR 88	0.00	7.69	16.97	109.6	109.4	744
APR 88	0.00	8.02	14.99	151.6	161.1	720
MAY 88	0.00	6.54	16.50	138.0	023.8	485
JUN 88	0.00	6.41	15.99	118.3	102.2	446
JUL 88	2.19	5.04	9.10	042.3	045.2	120
AUG 88	0.64	6.31	15.23	044.3	038.1	741

Table 12: Buoy 44004, Wind Speed and Direction Monthly Summaries

DATE	WIND SPEED			MEAN DIRECTION		RECORDS
YYMM	MIN	MEAN	MAX	(WEIGHTED)	(UNWEIGHTED)	
SPRING 87	0.00	6.55	12.80	053.0	044.3	560
SUMMER 87	0.00	5.42	12.63	051.9	052.0	1424
AUTUMN 87	0.00	5.84	15.61	173.6	189.0	1309
WINTER 88	0.07	8.37	21.33	134.9	136.8	623
SPRING 88	0.00	7.53	16.97	125.6	119.7	1949
SUMMER 88	0.00	6.23	15.99	060.9	053.4	1307

Table 13: Buoy 44004, Wind Speed and Direction Seasonal Summaries

DATE	WIND SPEED			MEAN DIRECTION		RECORDS
YYMM	MIN	MEAN	MAX	(WEIGHTED)	(UNWEIGHTED)	
MAY 87	0.00	5.57	14.51	044.8	036.4	668
JUN 87	0.97	5.08	10.67	043.3	042.2	707
JUL 87	0.97	3.62	9.70	035.0	351.7	696
AUG 87	0.97	4.19	10.67	100.0	075.8	689
SEP 87	0.97	5.08	13.55	316.0	346.6	612
OCT 87	0.39	7.40	17.39	057.1	046.2	198
NOV 87	0.29	8.31	25.67	110.2	094.9	654
DEC 87	0.29	9.03	22.63	125.5	119.5	671
JAN 88	0.49	7.91	20.15	096.4	100.2	723
FEB 88	0.19	8.35	18.82	083.9	104.5	684
MAR 88	0.29	7.57	16.52	096.8	090.8	741
APR 88	0.29	7.78	16.72	152.3	150.4	719
MAY 88	0.39	5.78	15.09	291.8	315.2	738
JUN 88	0.19	5.62	13.65	057.8	057.9	714
JUL 88	0.10	4.99	10.48	024.1	023.6	738
AUG 88	0.10	5.16	14.32	034.2	035.1	724

Table 14: Buoy 44008, Wind Speed and Direction Monthly Summaries

DATE	WIND SPEED			MEAN DIRECTION		RECORDS
YYMM	MIN	MEAN	MAX	(WEIGHTED)	(UNWEIGHTED)	
SPRING 87	0.00	5.57	14.51	044.8	036.4	668
SUMMER 87	0.97	4.30	10.67	045.4	041.7	2092
AUTUMN 87	0.29	6.84	25.67	088.8	053.4	1464
WINTER 88	0.19	8.41	22.63	108.0	109.6	2078
SPRING 88	0.29	7.04	16.72	114.5	087.9	2198
SUMMER 88	0.10	5.25	14.32	034.7	033.9	2176

Table 15: Buoy 44008, Wind Speed and Direction Seasonal Summaries

DATE	WIND SPEED			MEAN DIRECTION		RECORDS
YYMM	MIN	MEAN	MAX	(WEIGHTED)	(UNWEIGHTED)	
MAY 87	0.00	4.78	12.21	318.3	318.7	744
JUN 87	0.00	5.01	9.80	036.2	040.9	684
JUL 87	0.00	3.45	8.99	212.3	231.3	692
AUG 87	0.00	3.96	10.89	096.9	094.6	744
SEP 87	0.00	4.76	11.09	065.3	052.9	681
OCT 87	0.00	5.58	14.89	131.0	122.6	714
NOV 87	0.00	7.20	16.61	098.2	090.8	718
DEC 87	0.00	8.72	21.27	121.8	118.6	439
JAN 88	0.00	6.82	17.16	092.6	092.8	743
FEB 88	0.00	7.86	16.58	088.1	093.4	578
MAR 88	0.10	7.69	13.27	113.9	109.5	134
APR 88				No Data		
MAY 88	0.00	3.65	9.56	035.9	037.9	264
JUN 88	0.00	4.94	17.83	066.3	059.9	718
JUL 88	0.00	4.28	10.96	035.4	035.3	741
AUG 88	0.00	4.48	11.09	047.6	047.8	740

Table 16: Buoy 44011, Wind Speed and Direction Monthly Summaries

DATE	WIND SPEED			MEAN DIRECTION		RECORDS
YYMM	MIN	MEAN	MAX	(WEIGHTED)	(UNWEIGHTED)	
SPRING 87	0.00	4.78	12.21	318.3	318.7	744
SUMMER 87	0.00	4.13	10.89	057.9	065.0	2120
AUTUMN 87	0.00	5.86	16.61	098.4	080.1	2113
WINTER 88	0.00	7.64	21.27	102.8	102.8	1760
SPRING 88	0.00	5.01	13.27	076.9	060.0	398
SUMMER 88	0.00	4.56	17.83	046.6	045.1	2199

Table 17: Buoy 44011, Wind Speed and Direction Seasonal Summaries

D Maximum Expected Wave Heights for Five and Ten Year Return Periods

Heights are in meters.

MONTH	MEAN HS	FIVE YEAR MAX	TEN YEAR MAX
JAN	1.59	6.09	6.50
FEB	1.31	5.00	5.33
MAR	1.06	4.07	4.35
APR	1.13	4.31	4.60
MAY	0.93	3.57	3.81
JUN	1.02	3.91	4.18
JUL	0.90	3.44	3.67
AUG	0.92	3.51	3.75
SEP	0.80	3.06	3.27
OCT	1.15	4.40	4.69
NOV	1.31	5.00	5.34
DEC	1.37	5.25	5.60

Table 18: Martha's Vineyard Buoy, Maximum Expected Wave Heights

MONTH	MEAN HS	FIVE YEAR MAX	TEN YEAR MAX
JAN	2.42	9.30	9.92
FEB	2.38	9.16	9.78
MAR	2.16	8.33	8.89
APR	2.26	8.71	9.29
MAY	1.57	6.05	6.46
JUN	1.43	5.52	5.89
JUL	1.28	4.91	5.24
AUG	1.32	5.06	5.41
SEP	1.31	5.06	5.40
OCT	1.95	7.51	8.02
NOV	2.14	8.23	8.78
DEC	2.67	10.29	10.98

Table 19: Buoy 44004, Maximum Expected Wave Heights

MONTH	MEAN HS	FIVE YEAR MAX	TEN YEAR MAX
JAN		No Data	
FEB		No Data	
MAR	1.75	6.71	7.14
APR	1.96	7.49	7.97
MAY	1.25	4.78	5.09
JUN	1.17	4.49	4.78
JUL	0.95	3.65	3.88
AUG	1.07	4.11	4.38
SEP	1.19	4.54	4.83
OCT	1.56	5.97	6.36
NOV	1.95	7.48	7.96
DEC		No Data	

Table 20: Buoy 44008, Maximum Expected Wave Heights

MONTH	MEAN HS	FIVE YEAR MAX	TEN YEAR MAX
JAN	2.38	9.77	10.50
FEB	2.65	10.86	11.67
MAR	2.48	10.17	10.93
APR		No Data	
MAY	1.38	5.67	6.10
JUN	1.51	6.20	6.66
JUL	1.20	4.91	5.28
AUG	1.23	5.05	5.43
SEP	1.36	5.56	5.98
OCT	1.89	7.76	8.33
NOV	2.33	9.55	10.26
DEC	3.01	12.33	13.25

Table 21: Buoy 44011, Maximum Expected Wave Heights

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REPORT DOCUMENTATION PAGE	1. REPORT NO. WHOI-90-14	2.	3. Recipient's Accession No.

4. Title and Subtitle

Wind and Wave Climatology on the New England Shelf
May 1987 – August 1988

5. Report Date February, 1990

6.

7. Author(s)

Matthew M. Sharpe and Hans C. Graber

8. Performing Organization Rept. No. WHOI 90-14

9. Performing Organization Name and Address

The Woods Hole Oceanographic Institution
Woods Hole, Massachusetts 02543

10. Project/Task/Work Unit No.

11. Contract(C) or Grant(G) No.

(C)

(G)

12. Sponsoring Organization Name and Address

Funding was provided by the Office of Naval Research through contract Number N00014-86-K-0715 under the University Research Initiative Program

13. Type of Report & Period Covered Technical Report

14.

15. Supplementary Notes

This report should be cited as: Woods Hole Oceanog. Inst. Tech. Rept., WHOI-90-14.

16. Abstract (Limit: 200 words)

Wave power spectra from four waverider buoys on the New England Shelf and wind velocity records from three of those buoys and a fixed platform were analyzed. The data span the period from May 1987 through August 1988. Time series plots of significant wave height, mean wave period and modal (peak) period and distribution histograms of significant wave height, mean frequency and modal frequency are presented for the two buoys nearest to Martha's Vineyard. Time series plots of wind speed and vector velocity and distribution histograms of speed and direction are plotted for one buoy and the platform. For all stations, monthly and seasonal mean and extreme values of significant wave height, mean and modal wave periods, wind speed and mean weighted and unweighted values of wind direction are provided in tabular form. Five and ten year extreme wave height predictions are also calculated.

17. Document Analysis **a. Descriptors**

1. wind
2. waves
3. statistics

b. Identifiers/Open-Ended Terms

c. COSATI Field/Group

18. Availability Statement	19. Security Class (This Report)	21. No. of Pages
Approved for publication; distribution unlimited.	UNCLASSIFIED	179
	20. Security Class (This Page)	22. Price

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